WP1 Project Planning and Control

Title:	Final Report
Related to:	WP 2.1, WP 2.2, WP 2.3, WP 2.4 WP 3.1, WP 3.2, WP 3.3, WP 3.4 WP 4.1 WP 5.1, WP 5.2, WP 5.3, WP 5.4, WP 5.5, WP 5.6 WP 6.1, WP 6.2, WP 6.3, WP 6.4, WP 6.5
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Reference Documents

Document title	Ref	Date
FRESHMON Description of Work	DoW	13-Dec-2010

Contents

List of Abbreviations

Abbreviation	Description
BAW	Bundesamt für Wasserbau (Federal Waterways Engineering and Research Institute)
BfG	Bundesanstalt für Gewässerkunde (German Federal Institute of Hydrology)
DAP	Data Access Portfolio
DOW	Description of work
DWH	Data Warehouse
EO	Earth Observation
ISF-LUBW	Institut für Seenforschung (ISF) der Landesanstalt für Umwelt, Messungen und Naturschutz Baden–Württemberg (Lake Research Institute of the Environmental Agency Baden-Württemberg)
LfU	Bayerisches Landesamt für Umwelt (Bavarian Environment Agency)
SP	Service Provider
WP	Work Package

Executive Summary

The FRESHMON project aimed at creation of continuous and accepted downstream services for inland water monitoring at European level, through:

a) methodological research in improving and harmonizing different earth-observation (EO)-based methodologies for retrieving water constituents and water depth, and assimilating this with hydrodynamic models,
b) establishment of validation and quality management standards with end users,
c) providing customization, confidence and acceptance of EO products for end users and
d) establishment of an European business network of downstream inland water service providers and end-users.

These four project goals were achieved: Operational monitoring procedures for selected water constituents and water depth EO-based methodologies have been established, with solid theoretical background of the EO technologies and sustainable links to in-situ validation procedures. Links and intensive dialog with the end-user established from the very outset of the project have resulted in high quality standards and effectiveness in providing FRESHMON products and services. This created confidence and acceptance of FRESHMON EO products by the end-users. The consortium partners established a network of EO-product providers in their respective countries. FRESHMON products were introduced to a wider European community through manifold dissemination activities, by producing self-explaining easy to understand products and services, through personal training of the end-users, and an easy to navigate FRESHMON portal. The partners participated and contributed to the FP7 space Inland Water Workshop organized by REA, DG Enterprise and DG Environment with a White Paper, drafting the tangible vision of a harmonized Pan-European Inland Water Monitoring concept.

Summary description of the project context and the main objectives

In-land aquatic systems are under significant pressure from agriculture, economical development and climate change. The Directorate-General for the Environment titles “Water is life” on its website and underlines the meaning of water as a precondition for human, animal and plant life as well as an indispensable resource for the economy. European directives, like the Water Framework Directive (WFD), require the status of aquatic ecosystems to be sustained or improved. It entails environmental reporting obligations to EU Commission, where each member state shall regularly report on the environmental state of the aquatic ecosystems.

FRESHMON is an EU collaborative project to prepare the provision of High Resolution Freshwater Monitoring and Downstream Services. The main objective is to create continuous and well accepted downstream services for inland water monitoring at European level.

FRESHMON aims to do this by

- improving and harmonizing Earth Observation methodology for retrieving water constituents and water depth
- establishing quality control and validation standards
- providing customization, confidence and acceptance of Earth Observation products for end users
- establishing a European business network of Downstream inland water service providers and end users

1 Description of the main S & T results/foregrounds

1.1 WP1 Project Management

EOMAP as the coordinator of the FRESHMON project was responsible for the smooth management of all administrative issues including financial and monitoring of reporting.

In order to enable an effective collaboration, we established an

- FRESHMON internal wiki portal, hosting all relevant project information, work plans, meeting summaries and many more. This was a vital, effective and well used management tool
- Furthermore, we installed a subversion client and repository to host and share working documents on save base.

In order to improve the project management overview tasks quarterly reports to be submitted on the internal FRESHMON wiki were introduced. Every partner was obligated to summarize their work package activities for the FRESHMON project in a three months cycle. The main topics and the concrete outcomes are described in short headings or short sentences in a predefined table.

Another management instrument was the introduction of monthly teleconferences for the FRESHMON project (summer months only two month cycle). Open issues and questions are discussed by the consortium, represented at least by one representative of each partner. Summaries and actions items can be found afterwards on the internal wiki, see Figure 1.

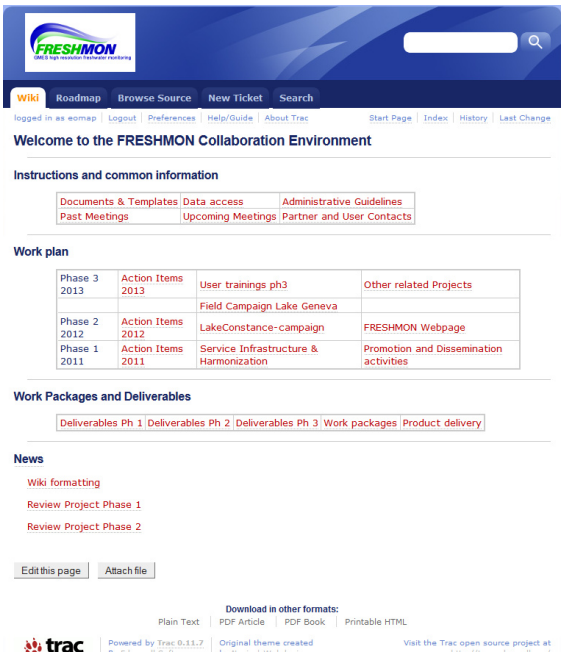


Figure 1: FRESHMON internal wiki

Project meetings and telephone conferences to specific tasks also gave time to elaborate important discussions within the consortium. An overview of the main project and review meetings is given in Table 1:

Table 1: FRESHMON project and review meeting

Date	Issue (Coordination)	Involved Partners
2010-12-07	Kick-Off Meeting, Gilching (EOMAP)	EOMAP, BC, WI, SYKE, EAWAG, PO
2011-04-05/06	WP meeting “Harmonization” Hamburg (Brockmann Consult)	EOMAP, BC, WI, SYKE
2011-09-07/08	WP meeting “Algorithms” Helsinki (SYKE)	EOMAP, BC, WI, SYKE, EAWAG
2011-12-07/08	Combined Review Meeting and Project meeting Brussels (EOMAP)	EOMAP, BC, WI, SYKE, EAWAG, PO, Reviewer
2012-05-16	Project meeting Wageningen (Water Insight)	EOMAP, BC, WI, SYKE, EAWAG
2013-01-16/17	Combined Review and Project Meeting Gilching (EOMAP)	EOMAP, BC, WI, SYKE, EAWAG, PO, Reviewer
2013-05-27	Project meeting Kastanienbaum, Switzerland (EAWAG)	EOMAP, BC, WI, SYKE, EAWAG
2013-11-20/21	Combined Final Project and Review Meeting, Brussels (EOMAP)	EOMAP, BC, WI, SYKE, EAWAG, PO, Reviewer

A total of 35 deliverables have been created and submitted. Three of the deliverables are confidential and only for members of the consortium, the others are public. In Table 2 the single deliverables ARE listed with the respective Identifier and the delivery date.

Table 2: Submitted deliverables in the FRESHMON project

Deliverable Identifier	Deliverable Description/Name	Nature	delivery date project month (DoW)
D11.1	Annual Report Ph1	Report	11
D11.2	Annual Report Ph2	Report	26 (24)
D21.1	User needs and Standards Summary Document	Report	11
D22.1	Standards and needs from EC directives	Report	7
D23.1	FRESHMON data Standards	Report	8
D24.1	Set of finalised Service Level Agreements (SLA) of all users	Report	20
D31.1	Service Provision technical infrastructure concept	Report	11
D31.2	Service Provision technical infrastructure prototype	Report	24
D32.1	Product format and meta data guideline	Report	11
D32.2	Service delivery system readiness report	Report	26 (24)
D33.1	Report on algorithms’ strengths/weaknesses	Report	11
D33.2	Report on algorithms’ improvements	Report	27 (26)
D34.1	Report on needs and standards of algorithms for future sensors	Report	30
D41.1	FRESHMON Downstream services Ph1	Demonstrator	10/11 (update)
D41.2	FRESHMON Downstream services Ph2	Demonstrator	24 (21)
D41.3	FRESHMON Downstream services Ph3	Demonstrator	34
D51.1	Report on Case Studies for practicability “One-dimensional modelling"	Report	10

Deliverable Identifier	Deliverable Description/Name	Nature	delivery date project month (DoW)
D52.1	Report on Case Studies for practicability	Report	23
D53.1	Report on modelling and FRESHMON services	Report	35
D54.1	Radiometric and in situ measurements of the ground truth for assessing the services	Other	11
D54.2	Radiometric and in situ measurements of the ground truth for assessing the services	Other	23 (18)
D54.3	Report on FRESHMON data quality and data comparability	Report	23 (18)
D55.1	Validation Protocol	Report	10
D56.1	CORE service validation	Report	18
D61.1	User training Ph1	Other	11
D61.2	User training Ph2	Other	24
D61.3	User training Ph3	Other	35
D62.1	Service Utility report Ph1	Report	11
D62.2	Service Utility report Ph2	Report	24
D62.3	Service Utility report Ph3	Report	35
D63.1	Policy brief FreshMon	Report	5
D63.2	Policy Brief FRESHMON	Report	36
D64.1	FRESHMON Project Web Portal	Other	4
D65.1	Service Portfolio FRESHMON	Report	13
D66.1	Business Model	Report	34 (31)

Further, we submitted via mail to the Project Officer (PO) following reports in addition:

- *Achievements Overview FRESHMON* in March 2013,
- *Addition User Feedback Table*, comprising the user comments so far and the reactions of the consortium in June 2013
- *D54.3 update: Update Report on FRESHMON data quality and data comparability*, with the validation results of phase 3 in October 2013

The defined milestones in the DoW have been achieved according to schedule, either through submitted deliverables or with acceptance of users and partners (see Table 3).

Table 3: Milestones of FRESHMON project

Milest. No	Milestone name	WP	Date	Means of verification	Status
101	FRESHMON Web Portal	64	5	FRESHMON Web Portal online	online
102	Annual Report Ph1	11,41	12	Services Ph1 delivered and accepted by user, Annual report Ph1 delivered	submitted
103	Ground Truth	54	18	Radiometric measurements & Ground Truth data provided	submitted
104	SLA set Ph2	24	20	SLAs for next phase signed by user	signed

Milest. No	Milestone name	WP	Date	Means of verification	Status
105	Annual Report Ph2	11,41	26 (24)	Services Ph2 delivered and accepted by user, Annual report Ph2 delivered	submitted
106	Algorithms	33	27 (26)	Report on algorithms' improvements delivered	submitted
107	Business model / Legal Framework	66	31	Business model / Legal Framework defined, documented and agreed with partners	submitted
108	Service provision Ph3	41	34	Services delivered and accepted by user	approved
109	Modelling and FRESHMON	53	35	Report on modelling and FRESHMON services delivered	submitted
110	Final Report	11	36	FRESHMON activities documented in Final Report incl. recommendations for sustainability of FRESHMON Services	submitted

1.2 WP2 Service Definition

1.2.1 User Need Assessment

As one of the first steps the FRESHMON consortium compiled, summarised and analysed the user requirements, which have been derived from user questionnaires and interviews performed between service providers and users (*D21.1*). It has turned out that the users are very interested in retrieving products based on remote sensing data and that they have clear ideas on how to integrate such products. Figure 2 illustrate the currently used practices and their envisaged development in the upcoming years.

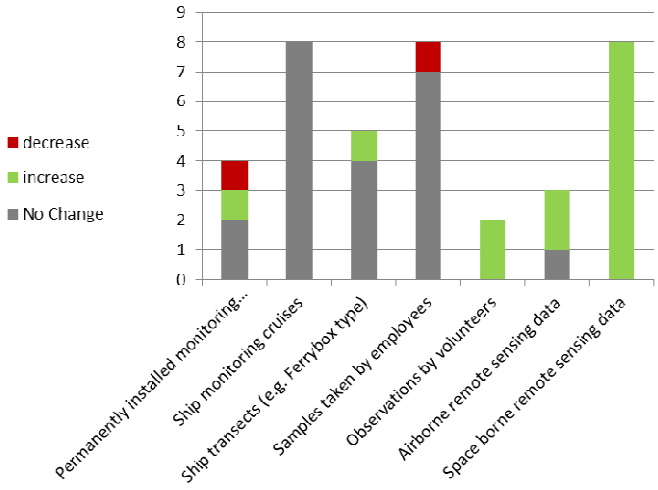


Figure 2: Illustration of the currently used practices and their development

However, the quality of the products is a critical point from the user perspective and therefore have been investigated carefully in the Service Development (see 1.3) and the reliability of products have been demonstrated to users in the validation activities.

1.2.2 EU-Directive Requirements

Next to the user needs, also the FRESHMON consortium analysed the EU directives that are directly related to inland, coastal and marine waters: Water Framework Directive, Marine Strategy Framework Directive, Habitats Directive, Flood Risk Directive, Nitrates Directive, Bathing Water Directive and Urban Wastewater Directive. The European research projects related to the use of EO in the application of the directives and for developing tools for the needs of the directives were reviewed (see Table 4).

Table 4: Summary of required features of different directives; Medium resolution 300-1000 m (M), High resolution 10-30 m (H), Very High resolution 1-4 m (VH). Key features of a directive are distinguished from supporting features by bold letters.

Feature/variable	**Variable detailed**	**WFD** Water	**MSFD** Marine[1]	**HD** Habitats[2]	**FRD** Flood	**ND** Nitrate	**BWD** Bathing	**UWD** Urban
Chlorophyll a		**M,H**	**M**			H	H, VH	H, VH
Cyanobacteria (Phycocyanin)			**M**				H, VH	
Surface algal blooms			M, H				H, VH	
Total suspended matter		H						
Turbidity		H	M, H					
Transparency	Secchi	M,H	M, H	VH			H, VH	
	Kd			VH				
CDOM		H[3]						
Temperature		M,H	M				H, VH	
Floating and emergent vegetation (type and abundance)	Macrophytes	**VH**	**VH**	**VH**				
Submerged vegetation (type and abundance)	Macrophytes	**VH**	**VH**	**VH**				
	Macro-algae	**VH**	**VH**	**VH**				
Bathymetry (shallow areas)			VH	VH				
Bottom type	Particle size		VH	VH				
	Periphyton		VH	VH				

Feature/variable	Variable detailed	WFD Water	MSFD Marine[1]	HD Habitats[2]	FRD Flood	ND Nitrate	BWD Bathing	UWD Urban
Water extent					**H,VH**			

[1] Marine Strategy Framework Directive does not unambiguously define the key variables. The classification of the importance of the features presented here is based on subjective evaluation.

[2] Habitats Directive does not include detailed information of the features. The features presented here are based on discussions with habitat experts.

[3]Not mentioned in the directive, but CDOM is e.g. in Finland used in the characterization of water body types of lakes.

The main conclusion was that the implementation of all the directives would benefit from high or very high resolution EO products. For example, high resolution Chl-a product would be useful for most directives.

1.2.3 Harmonization, INSPIRE and Data Management

The FRESHMON consortium put effort studying metadata standards, web-interfaces and best practices for distributed service architectures. As result of this work package, the consortium created an extended metadata standard, according to the INSPIRE standards. From the point of view that metadata built the basis for upcoming work packages and services, the harmonization of metadata was created in close collaboration with all partners and with respect to Deliverable 3.1, 3.2 and 6.4. Also the naming conventions with abbreviations for products and sensors have been created in this context. For detailed information about the common FRESHMON data standards for service provision please refer to deliverable *D23.1 FRESHMON data standards.*

Common colortables for the product visualization for demonstration or promotion purposes have been chosen, TSM should be in blue-yellow-red, CHL in rainbow color scheme and yellow substances in a brownish color scheme. Harmonization of flag values have been discussed in the consortium, but are too processor depended for a common standard evolution.

Dealing with the issue of data management, the consortium followed the registration procedure according to the GMES Data Access Portfolio (GMES-PMAN-EOPG-TN-11-0006). After defining the areas of interest (AOI) of each service provider, a large amount of high resolution scenes have been ordered, using first the order form and later the online Offline mapping function (https://cds-spci-es.eo.esa.int/gscda/), see also table Table 5:

Table 5: Overview of high resolution data ordering covered by the GSC-Datawarehouse or budget allocated in the DoW

Scene date	Sensor	Data source	Area	Purpose
2011-10-24	IKONOS	Data Warehouse	Lake Constance	Service provision
2011-08-19	WorldView-2	Data Warehouse	Lake Constance	Service provision
2012-05-03 2012-05-04	RapidEye	Budget from EOMAP Other costs for EO-Data not covered by GSC-DA	Lake Constance	Field campaign validation

Scene date	Sensor	Data source	Area	Purpose
2012-05-25 2012-05-26	SPOT	Budget from EOMAP Other costs for EO-Data not covered by GSC-DA	Lake Constance	Field campaign validation
2012-05-25 2012-06-26	ASTER	Budget from EOMAP Other costs for EO-Data not covered by GSC-DA	Lake Constance	Field campaign validation
2012-06-06 2012-06-20	RapidEye	Data Warehouse	Finland	Service provision and validation
2012-06-21	SPOT	Budget from EOMAP Other costs for EO-Data not covered by GSC-DA	Finland	Service provision and validation
2011-04-29	WorldView-2	Data Warehouse	Finland	Service provision
23.06.2010, 21.07.2011	RapidEye	Data Warehouse	Kotka, Finland	Validation
14.08.2012	RapidEye	Data Warehouse	Elbe, Germany	Case Study
16.05.2013	RapidEye	Data Warehouse	Talvivaara, Finland	Validation
15.07.2013	RapidEye	Data Warehouse	Greifensee, Switzerland	D53.1, Validation
14.05.2013	RapidEye	Data Warehouse	Lake Geneva, Switzerland	Field campaign validation
12.08.2012, 19.08.2012	RapidEye	Data Warehouse	Markermeer, Netherlands	Validation
20.07.2013	RapidEye	Data Warehouse	Lake Baikal, Russia	Field campaign validation
03.05.2013, 24.06.2013	WorldView-2	Data Warehouse	Tvärminne, Finland	Field campaign validation
04.09.2012	WorldView-2	Data Warehouse	Kotka, Finland	Validation
23.03.2012	WorldView-2	Data Warehouse	Markermeer, Netherlands	Validation
07.2013	WorldView-2	Data Warehouse	Lake Baikal, Russia	Validation
12.11.2011, 30.04.2012	GeoEYE	Data Warehouse	Markermeer, Netherlands	Validation
29.08.2012	GeoEYE	Data Warehouse	Ijsselmeer, Netherlands	Validation
26.07.2012	ASTER	Budget from EOMAP Other costs for EO	Elbe, Germany	Case study
23.07.2008, 28.03.2012	SPOT-5	Budget from EOMAP Other costs for EO	Markermeer, Netherlands	Validation

A shift of the FRESHMON quota in the GMES Data warehouse was necessary in the second phase in order to guarantee a useful handling of the conditions connected with the specification of the Data Access Portfolio (DAP). In comparison with commercial providers, the minimum order sizes differ in an unfavorable way, e.g. instead of 25sqkm for commercial orders it is 400sqkm in the DAP. Also, a choice of specific satellite sensors is only possible using archive imagery.

For the provision of services and product s, like near real time delivery, the FRESHMON service providers acquired also other medium and high resolution data sources, like MODIS 500 m and 250 m (NASA), MERIS 300 m (ESA) or Landsat 30 m (NASA).

1.2.4 SLA Evolution and Finalization

With the Service Level Agreements the responsibilities of the service providers and the user are defined. Service specifications, product quality and provision of validation data are determined in detail and are user specific for each agreement.

After setting up a FRESHMON SLA template (see *D24.1*), all Service Providers specified the template according to their particular, individual service requirements. A variety of services and products are covered in these SLAs, have been discussed with the users and serve as the basis for the development and dissemination of the new water monitoring service line. In course of the project the users from SYKE, WI, BC and EOMAP signed the SLAs.

A SLA has been set up with the FP-7 funded GLaSS and INFORM project, dedicated to the development of new tools, algorithms and methods to turn the large amount of data from the Sentinel satellites into information for water management. It covers the exchange of deliverables, products as well as data sets collected during the field campaigns upon request.

1.3 WP3 EO Services R & D

1.3.1 Infrastructure Development

A comprehensive analysis of the existing technologies for data dissemination and data search in a distributed service network has been outlined in the *Service Provision technical infrastructure concept* document (*D31.1*). The relevant OGC standards for data visualization (WMS), data access (WCS) and data search (CSW) were introduced. The document also gives an overview of the software that can be used to provide the needed functionality.

Literature studies and prototype implementations of different elements of the infrastructure have been performed in order to get an overview and impression on the single functionalities, pros and cons of different systems. The document summarizes the common understanding of the consortium partners with respect to the system structure, interfaces between partners and the FRESHMON portal, technologies used for implementing the interface functionality and reasons for the selection of a certain technology.

According to the concept of the implementation of the FRESHMON services, information and products can be accessed through following means:

1. FRESMON-portal: The portal is a website that contains information about the FRESHMON services: What is available, how to find specific data, how to access it and so on.
2. Metadata catalogue service (CSW): FRESHMON-CSW is a part of the FRESHMON-portal. It contains metadata of the products of all service (systematically harvested from the catalogues of the consortium partners). The user can search the catalogue for specific products with search terms such as date, area of interest, parameters and service provider.
3. WMS for image access: After finding products the user can download the data from Web accessible folders (WAF) that are hosted by the service provider that processed the data. Other standardized technologies to access and view the data are Web Coverage Service (WCS) and Web Mapping Service (WMS). A common WCS/WMS that contains all FRESHMON data was agreed not be implemented due to time and technical constraints.

   For an example of a WMS implemented on service provider side, see an example of SYKE: *http://paikkatieto.ymparisto.fi/arcgis/rest/services/*

Deliverable *D31.2 Service Provision technical infrastructure prototype* describes in detail the individual processing chains of the partners. The overall architecture of FRESHMON infrastructure prototype for water quality product services is delineated in Figure 3:

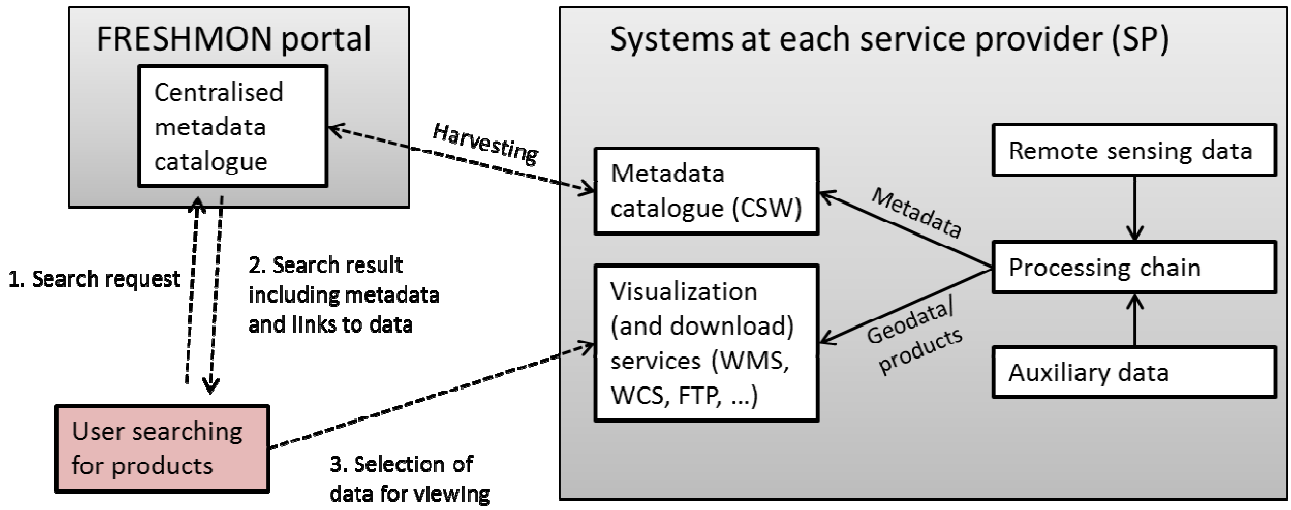


Figure 3: Overall architecture of FRESHMON infrastructure prototype for water quality product services.

1.3.2 Interface setup

Taking into account the concept developed within WP 3.1 (Infrastructure development), agreement was made on data format and meta data specifications. Prototype CSW and WMS service interfaces

were set up to test the functionality scalability, and interoperability. The CSW interface implementation was done with Geonetwork, an open source tool for managing metadata. The prototype can be found here: *http://catalog.freshmon.eu/srv/en/main.home*. Harvesting other CSW services was tested. The deliverable *D32.*1 *Product Format and Metadata Guidelines* contains user instructions on what software can be used to open and view the image products (GeoTIFF-files) and how to view information written in the metadata. The metadata elements that can be used as search criteria for data products are introduced.

The partners have integrated the Freshmon specific elements into their existing processing chains and/or further developed their processing chains in order to meet the defined FRESHMON outputs and serve the requirements of the individual users. *D32.2 Service delivery system readiness report* describes which of the processing elements have been implemented at each service provider (see Figure 4, Figure 5, Figure 6, Figure 7).

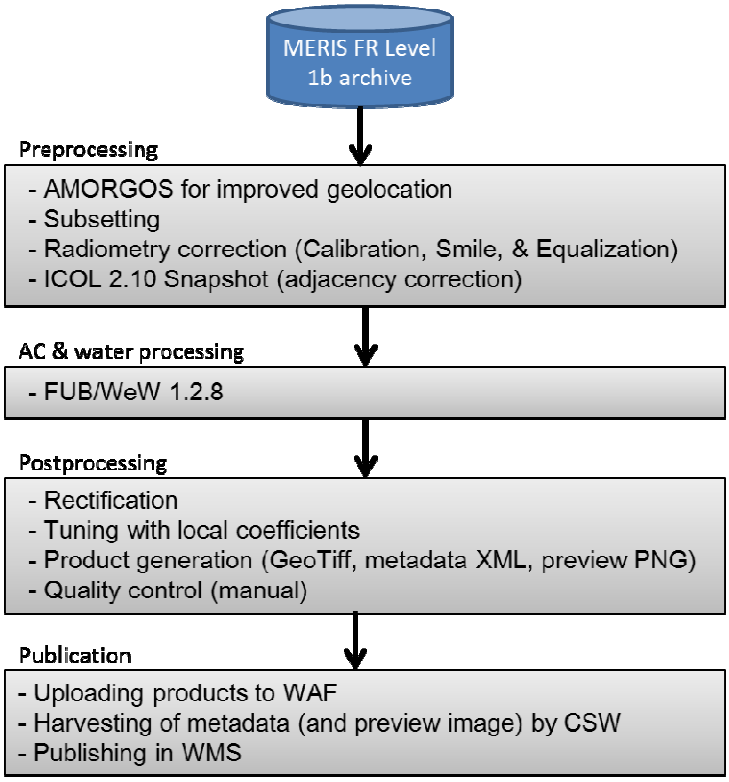


Figure 4: FRESHMON MERIS processing at SYKE.

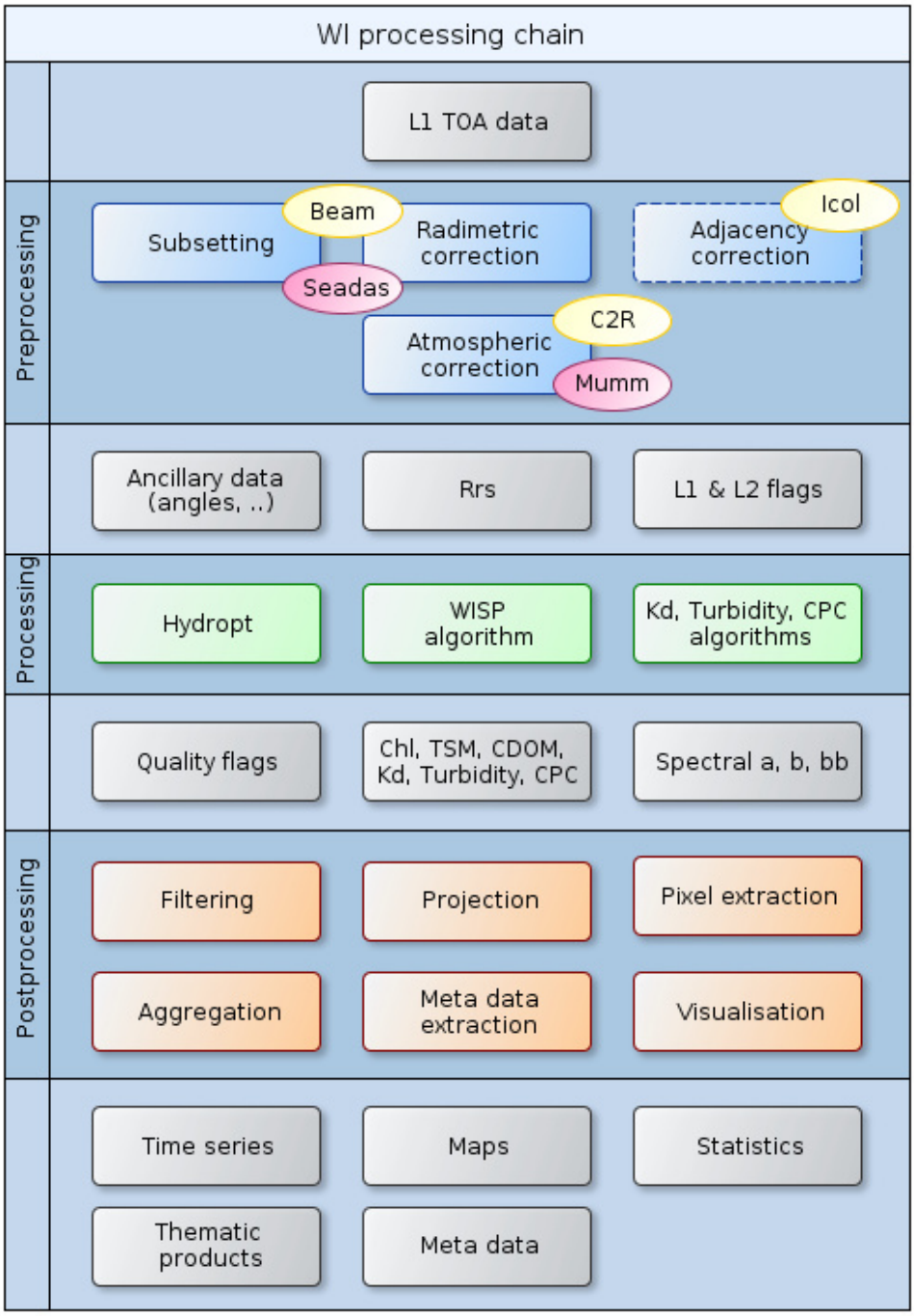


Figure 5: Processing Scheme FRESHMON processing at WI

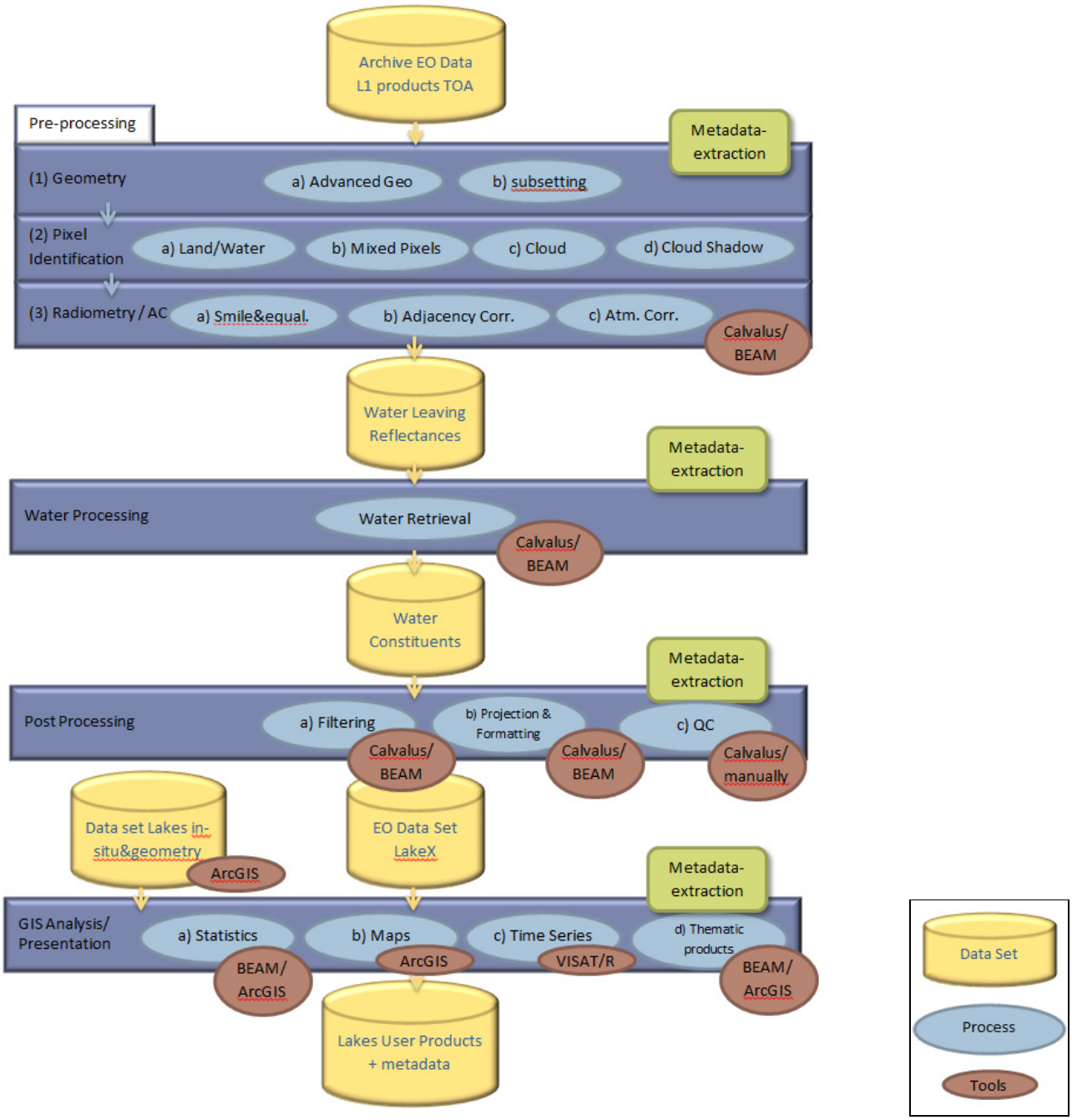


Figure 6: Processing Scheme FRESHMON processing at BC

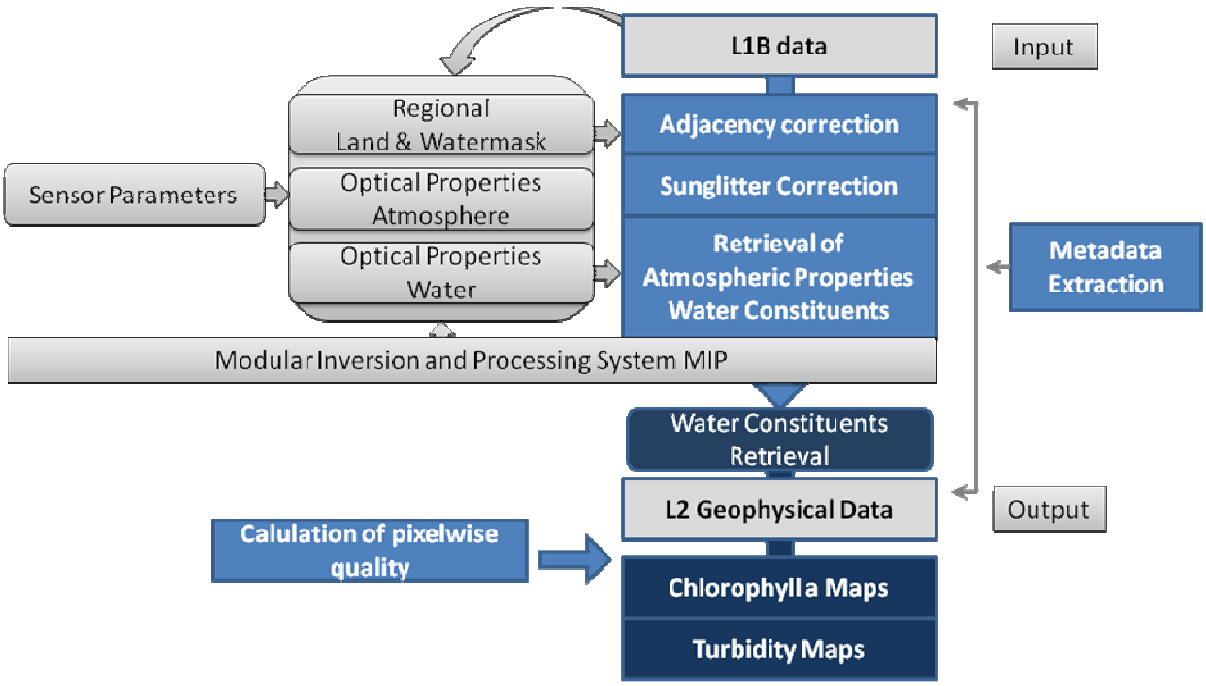


Figure 7: Processing Scheme FRESHMON processing at EOMAP

The implementation work for this has mainly been taken place in phase 2. During phase 3, individual improvements on service provider level have been performed in order to fulfill the individual user needs. E.g. additional aggregation steps were implemented in order to provide regional and temporal statistics to the users. Furthermore, harmonization between EOMAP and BC was performed for the delivery of products for German users (BAW and BfG). Here, we compared the different output products from MERIS and Landsat in order to provide the same parameters. Flagging and formats needed to be adjusted as well.

1.3.3 Algorithms

The EO service providers (EOMAP, WI, BC, SYKE) improved their technologies to generate water quality and water depth maps from multiple earth observation satellites. A dedicated algorithms workshop in Helsinki was conducted to summarize the status, discuss challenges and proposed technical solutions to improve the products. A report on algorithms strength and weakness is provided with deliverable D33.1 (not public). The main improvements are:

- EOMAP improved their algorithms for the adjacency corrections, sunglint, improved the flagging, introduced quality measures, run extensive runtime tests with various satellite data, and coordinated further developments to install and control the value adding processors within a fully automated product generation environment. The MIP system architecture and structure of the radiative transfer data bases was systematically analyzed to increase processing time, storage usage and allow further complex improvements of the inversion process, accounting e.g. better the bidirectional underwater effects in shallow water environments.
- BC is applying a number of preprocessing steps to MERIS FR data in order to retrieve good input products for the water retrieval in lakes. Existing algorithms which were originally developed for the water retrieval in coastal waters were tested and finally the best suited was applied to the inland waters. The pre-processing and valid pixel filtering has been improved during the course of the project. Concepts for the integration of FRESHMON products and in-situ data (provided by the users) within a GIS systems have been developed together with Finnish and Estonian Users.
- WI adapted and tested their WISP algorithm and preprocessing to be able to process high resolution data. Changes were applied on the processing chain as a whole to be compliant to the FRESHMON standards of formatting and metadata. The algorithms used by the WISP instrument and WISPweb portal were also updated and tested for inland waters. For the WISP algorithm, a new method of estimating the standard error in the retrieved concentrations has been implemented. Furthermore, additional flags are written out from the WISP algorithm that indicates problems with the parameter retrieval: maximum number of iterations reached and fallback value used.
- SYKE tuned their MERIS chl-a products using in situ chl-a data measured by an automated raft in Lake Säkylän Pyhäjärvi.

A detailed overview of improvements made during FRESHMON is given in Table 6 by processing step and service provider:

Table 6: Overview improvements by processing step and service provider

Processing Step	Improvements	SP
Sensor calibration	Sensor calibration for new and existing sensors	EOMAP
Pre-processing	Pixel classification and flagging	BC, WI, EOMAP
Adjacency Effect	ICOL ADJCOR	BC EOMAP
Atmospheric correction	CoastColour	BC
Water retrieval	FUB additional bands FUB product tuning WISP adaptation to MODIS WISP improvements MIP inversion process	BC SYKE WI WI EOMAP
Quality Products	WISP error product MIP quality measure	WI EOMAP
Filtering valid pixels	Improved flagging, stat. Analysis Buffering	BC SYKE
Extraction of temporal or spatial statistics	Tool development	BC
Modelling	Integration of EO data	EAWAG

1.3.4 Algorithms for future sensors

During phase 2, the work within the work package on future sensors did start. The Sentinel-2 workshop was attended by 2 FRESHMON partners (SYKE and BC) and a presentation was given by S. Koponen on "High resolution satellite data needs in Finnish Coastal Waters and Lakes[1]". It is pointed out how the higher spatial resolution will improve the availability of EO data for smaller lakes. Further, simulated

[1] Koponen, S., Kallio, K., Attila, J. Pyhälahti, T., Kaitala, S., Anttila, S., Alasalmi,H., Kervinen, M. (2012): High Resolution Satellite Data Needs in Finnish Coastal Waters and Lakes.-Symposium

spectra were used to test single band and band ratio algorithms. During the Sentinel-3 WS in ESRIN (October 2012), a poster on “Requirements on Pre-processing for Retrieval of Water Quality of Lakes with Medium Resolution Data” has been presented, showing the suitability and limits of Sentinel-3 data for lake monitoring. However, a lot of effort needed to be performed due to the loss of MERIS and therefore, not all partners could start their work in preparing new sensors, rather than worked on the switch to existing sensors such as MODIS. EOMAP started the investigation of the impact of SENTINEL 2 and 3 channel response functions to the water quality and water depth products, and analyzed algorithm improvements e.g. for the retrieval of aerosol properties, cirrus and atmospheric correction. Within the GlaSS project (http://www.glass-project.eu/) the upcoming satellite sensors Sentinel-2 and -3 will be further investigated as also four partners of the consortium are also involved in this project. INFORM, another FP7- project, started just after FRESHMON, aims to develop novel and improved user-driven products for inland water quality monitoring by using innovative methods integrated into biogeochemical models which fully exploit the capabilities of upcoming earth observation mission, like Sentinel 2 and 3 or EnMAP. EOMAP is part of this consortium as well.

As raised during the Sentinel 3 Validation Team Meeting in November 2013, inland water products have to be considered in future discussions as well. This has been recognized by ESA.

1.4 WP4 Service Provision

From the first phase of the project on, the FRESHMON service providers started delivering EO products to the users. Using different satellite sensors from low (e.g. MODIS with 500m) to high spatial resolution (e.g. RapidEye with 5m), water quality products comprising Total Suspended Matter concentrations, Turbidity, Colored Dissolved Organic Matter content, Chlorophyll-a, Phycocyanin or Z90 (signal penetration depth) have been provided to the users.

A total of over 2000 satellite scenes have been processed by the different partners and over 3000 water quality products were delivered to several users across Europe, see Table 7 for an overview of the delivered resolution and number of products.

Table 7: Resolution and number of products delivered to FRESHMON users

User	Resolution	Number of products/scenes
BAW Federal Waterways Engineering and Research Institute	Landsat 30m	32
	MERIS 300m	133
	MODIS 500/250m	47
	RapidEye 5m	6
BfG German Federal Institute of Hydrology	Landsat 30m	47
	MODIS 500/250m	34
	RapidEye 5m	6
Cornell University	MODIS 1000m	242
Delaware	WV-2	4
Deltares (+RWS Rijkswaterstaat)	Formosat 8m	10
	MERIS 300m	484
EOMAP	MERIS FR 300m	full missions, Alpes
LfU Bavarian Environment Agency	Landsat 30m	34
	MERIS 300m	62
	MODIS 500/250m	50
	RapidEye 5m	4
LUBW Environmental Agency Baden-Württemberg	Landsat 30m/500m	3
	MODIS 500/250m	451
	RapidEye 5m, SPOT, ASTER	6
	WV-2 2m	1
LUBW (ISF) Lake Research Institute of the Environmental Agency Baden-Württemberg	MERIS 300m	60
	MODIS 250m	14
	RapidEye 5m	2

User	Resolution	Number of products/scenes
Department for Agriculture, Environment and Consumer Protection Mecklenburg-Vorpommern	MERIS 300m	0 (report)
SYKE	Landsat 30m	1
	MERIS 300m	82
	MODIS 500m	1
	RapidEye 5m	12
	WV-2 4m	2
Valencia	Landsat 30m	15
WVZ Water Supply Zurich	MERIS 300m	2 (demo)

First, most attention was paid to setup a sustainable service production chain for multiple satellite sensors and to produce the products already with the harmonized standards as documented in delivery 23.1. The defined naming conventions, metadata standards and service validation, described in deliverable D23.1 and D55.1, were in most cases applied.

With the deliveries in the following phases, the portfolio was extended with water depth products, statistics, like monthly mean, polygon and point information as well as other data formats, like kmz for the visualization in Google Earth. Moreover, detailed technical reports have been added to the deliveries, including also the analysis of different case studies and description of results.

In Figure 8 two examples of delivered products are shown.

a) b)

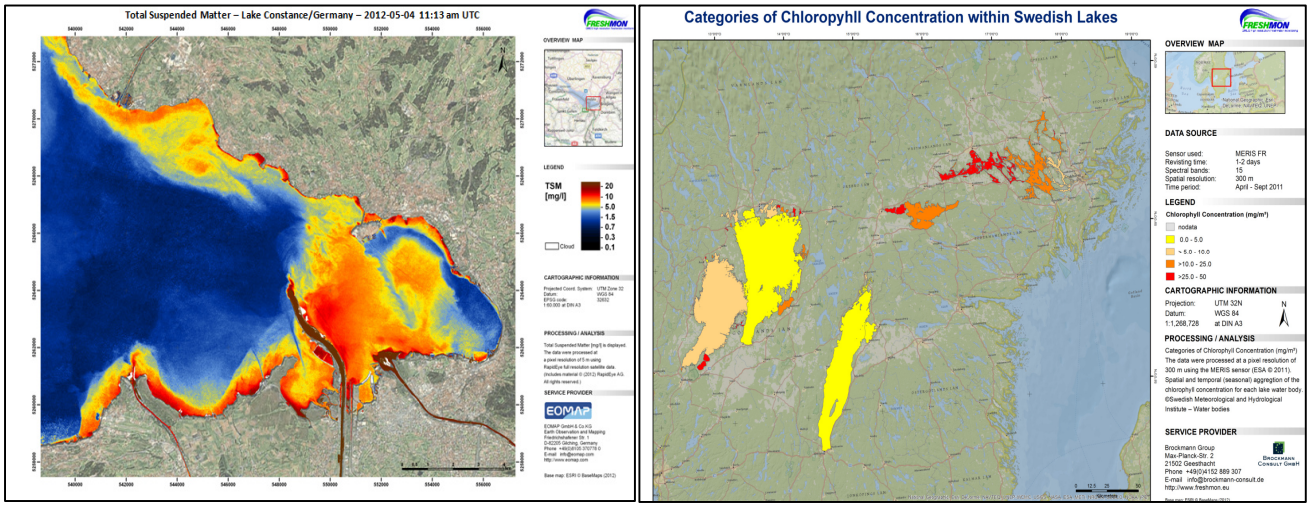


Figure 8: Two Examples of FRESHMON products: a) Total Suspended Matter using RapidEye 5m resolution data and b) spatial and seasonal aggregated Chlorophyll-a from MERIS

1.5 WP5 Validation & Assimilation

1.5.1 One-dimensional Modelling

An integral component of the water quality product development is the ability to provide a continuous-in-time picture of important water quality indicators, such as Chlorophyll-a (Chl-a) and total suspended matter (TSM). With the current generation of publically-available satellite technology, it is not possible to continuously monitor inland water bodies. Therefore, the FRESHMON project proposes to utilize numerical lake modelling in order to "fill in the gaps" between the available satellite images. The ability to synchronize these two technologies-- satellite remote sensing and numerical lake modelling -- forms a major research and development goal of the FRESHMON project.

A first step in attaining this goal is the development and calibration of a one dimensional (1D) hydrodynamics model to predict lake thermal stratification. As a testing site for the 1D model development, we have chosen Lake Greifensee, Switzerland. This lake was the location of an intensive field campaign during summer 2011. See Figure 9 for a vertical profile as one of the results of the field campaign.

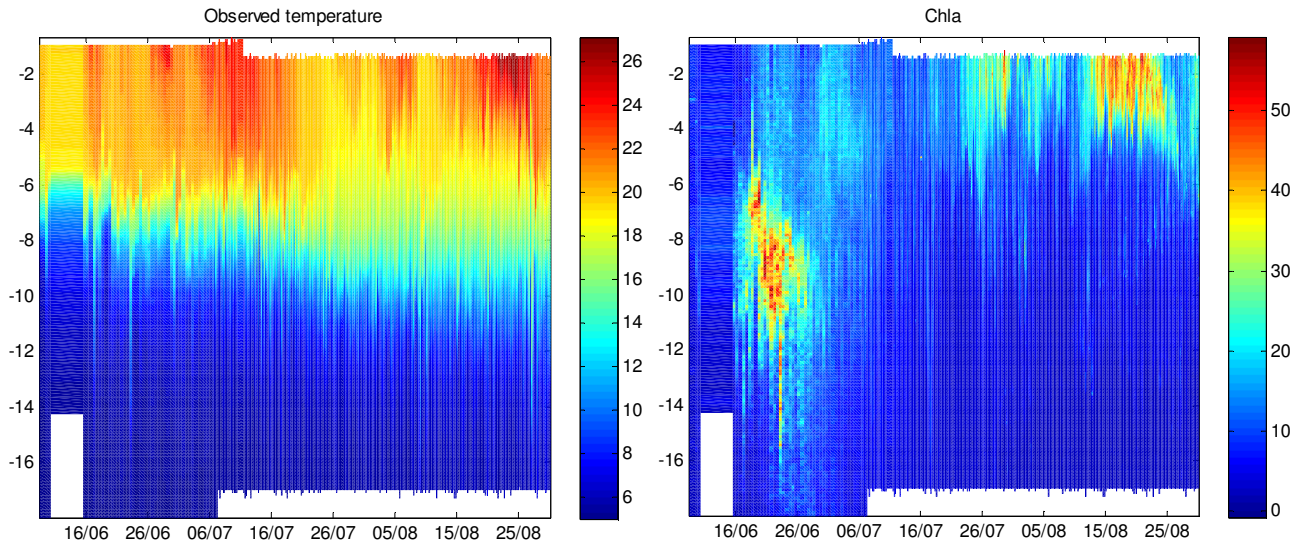


Figure 9: Vertical profile of Chlorophyll-a in µg/l and temperature in Lake Greifensee, taken with a multi-parameter profiler

1.5.2 Interpretation and modeling of 2D structures

The goal of WP5.2 was to capture horizontal variability in remotely-sensed magnitudes by ground-truth field campaigns, to be compared to satellite observations. These field campaigns had necessarily to be performed in a big lake (Lake Constance). Field trips organized by EAWAG and by LUBW-ISF Langenargen encompassed from May to August 2012. The ground-truth work measured turbidity, also called particle concentration or total suspended matter (TSM) by direct water sampling, optical

transmission and above-surface radiometry (WISP). Description of the trips, acquired data, results, and interpretation can be found in *D52.1* and Table 8 a summary of the measurements.

Table 8: In situ measurements and satellite images for field campaign at Lake Constance

Date	Measurements	Satellite Images	participants
03.05.2012	WISP	RapidEye, MODIS	EAWAG
04.05.2012	WISP	RapidEye, MODIS	EAWAG
11.05.2012	CTD, WISP, FILT	MODIS	EAWAG, ISF
25.05.2012	CTD, WISP, FILT, RAMSES	ASTER, SPOT, MODIS	EAWAG, EOMAP
25.06.2012	CTD, WISP, FILT	Cloudy	EAWAG, ISF
26.06.2012	CTD, WISP, FILT	ASTER, MODIS	EAWAG, ISF
27.06.2012	CTD, WISP, FILT	MODIS	EAWAG, ISF
25.07.2012	CTD, WISP, FILT	MODIS	EAWAG, ISF
26.07.2012	CTD, WISP, FILT	MODIS	EAWAG, ISF
08.08.2012	CTD, WISP, FILT	MODIS	EAWAG

Another more experimental goal was to investigate hydrodynamic models to predict the fate of suspended particles in lakes and to assimilate satellite data as boundary and initial conditions, as well as for correcting simulation results. Although this is a cutting-edge research topic and there are not relevant results in the available literature, some results are also included in *D52.1*.

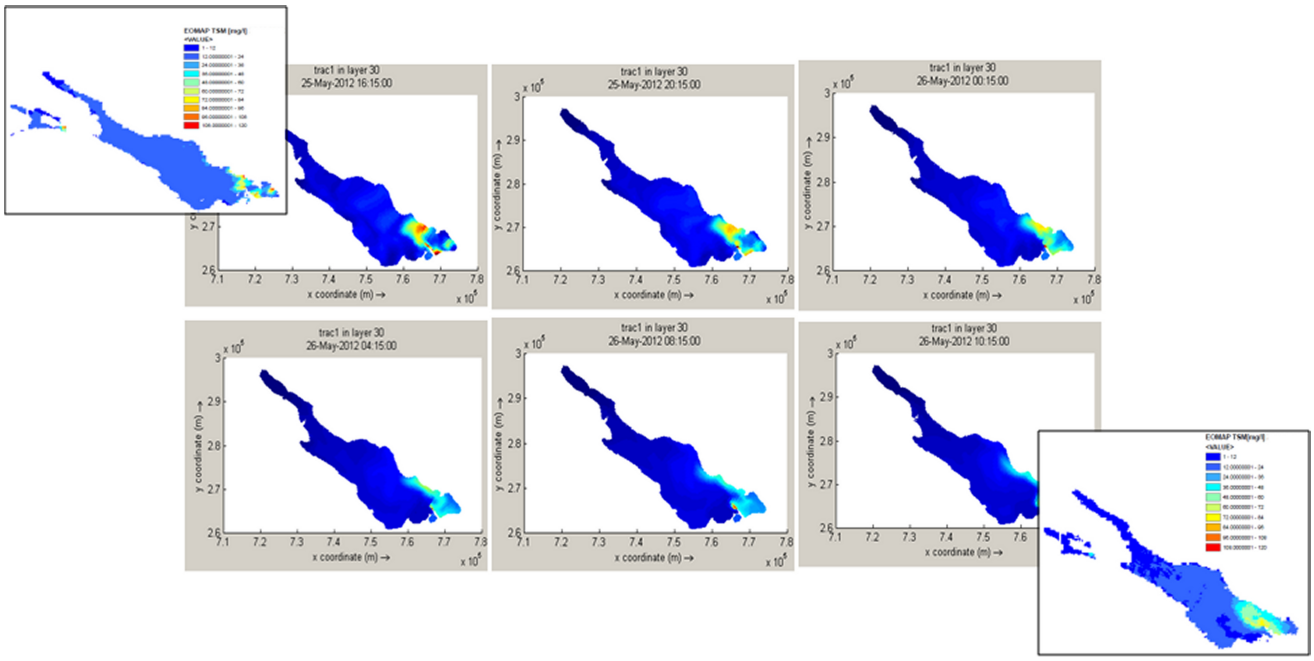


Figure 10: Simulation results with satellite image as input for an example in May 2012

Despite the surprising similarities between the modelled data and the satellite observations, some limitations of the modelling make the results still not ready for direct comparison:

- Current input wind is the result of a 2D interpolation of meteorological data coming from stations at the shore. Despite general processes like Foehn effect are well characterized, the fine details of the wind field structure in the lake are lost. To improve this part, a better modelling of the wind field over the area is needed
- The modelling of the thermal stratification was performed through a rather simple k-ε closure which can be replaced in a future version of the code
- In order to calibrate the modelled thermal stratification, more data is needed over space and time, which would include moored thermistor chains and water current measurements (Rubbert and Köngeter 2005)
- For the sake of simplicity, TSM is modelled as a passive tracer, which means that it does not affect density or temperature of the lake's water. In reality, TSM can change the density of water because its composition is different, leading to a different density stratification than predicted. It is complicated to improve this part, since it would require to change the equation of state for density in order to include the dependence on TSM
- The assimilation procedure consists just on an average between the simulated and the satellite-observed TSM. This part could include a weighting factor depending on the quality of the satellite observations to give more importance to the latter or the modelled TSM
- New research can be conducted to answer the question of whether or not quantitative vertical information can be extracted from the remote sensing products, and if so, to incorporate this information into the modelling

1.5.3 Linking of modeling with EO services

In this WP, we linked hydrodynamic and biogeochemical 3D simulations (ecosystem modelling) to CHL MERIS observations during summer 2011 at a eutrophic lake in Switzerland (Greifensee). The modelling filled the temporal gap between the observations, see Figure 11 for an example of the linkage.

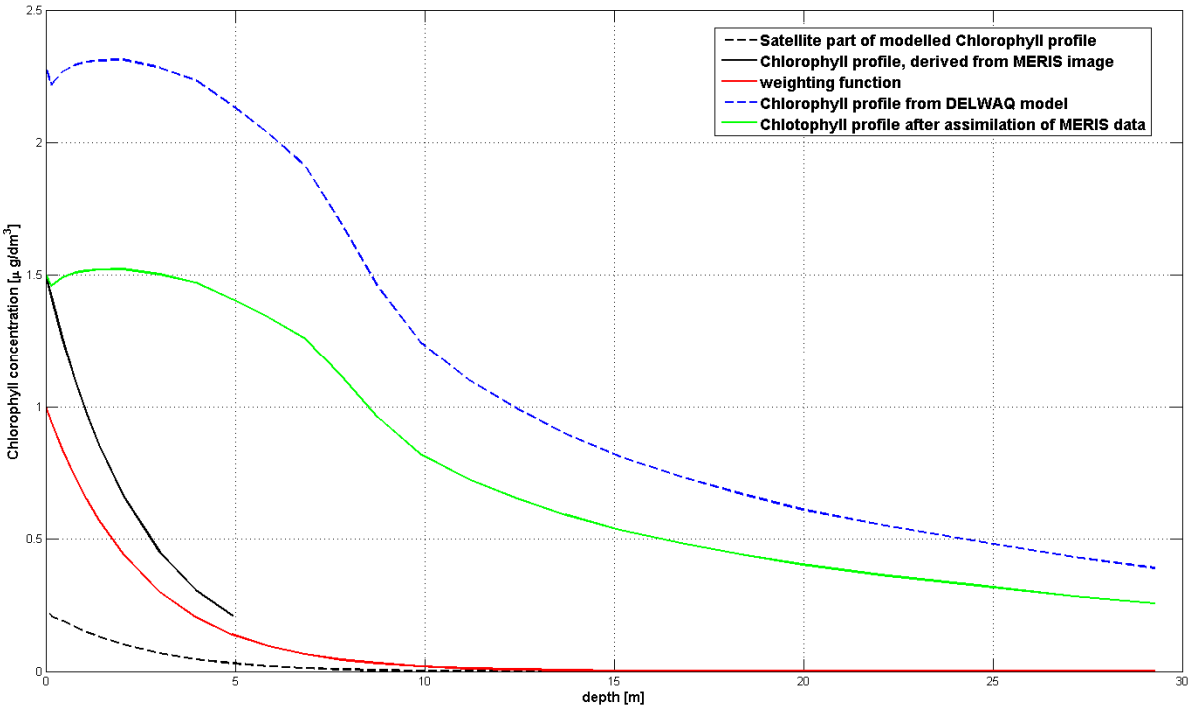


Figure 11: Example linkage of modeled chlorophyll vertical profile (blue curve) with chlorophyll profile observed by satellite sensor (black curve); resulting with corrected profile (green)

Complementary, observations were assimilated into the model and corrected its results. Our conclusions are that

1) the model needs intensive field and computer work for calibration and periodic validation, and this must be performed independently for every water body.
2) MERIS observations were subjected to a high degree of uncertainty, so that data assimilation could bias the model.
3) in the future, the model should also simulate the underwater light field as an input for primary production and thermal budget. The magnitude to be assimilated would be the above-surface remote-sensing reflectance, which is physically well defined and algorithm-independent.

1.5.4 Calibration and validation

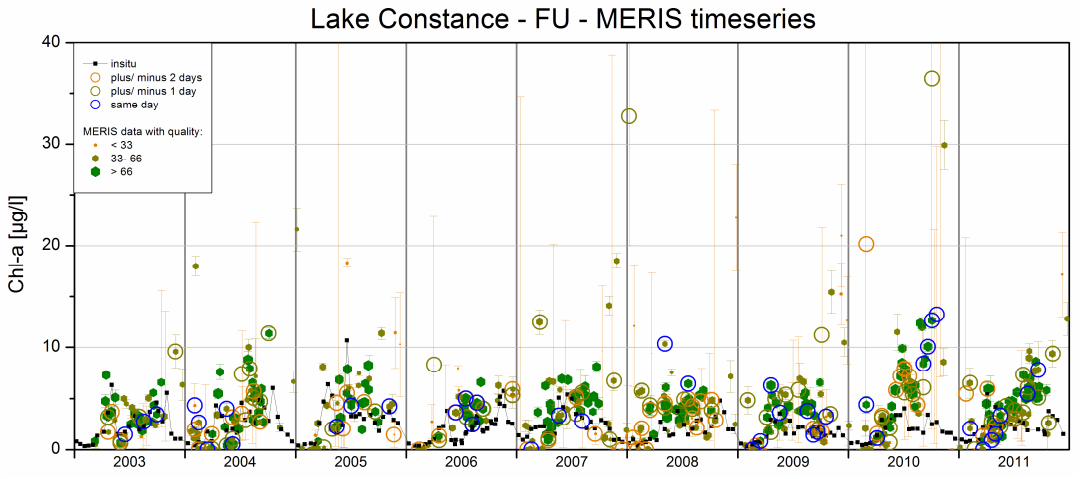
FRESHMON satellite products were validated in Finland (MERIS, Rapid Eye, WorldView), Germany and Switzerland (Landsat 7 & 8, MERIS, RapidEye, ASTER, SPOT, MERIS, MODIS), and the Netherlands (MERIS and MODIS).

As overall result, the improved remote sensing technologies to monitor inland waters deliver consistent products in long-term tests for the most relevant parameters, namely turbidity and related suspended matter, Chlorophyll content, and organic absorption. Figure 12 a and b show the comparison for a decade of in situ measurements by the International Water Protection Commission IGKB for Lake Constance with satellite retrieved Chlorophyll (from MERIS) and suspended matter (from MERIS and Landsat-7). Figure a shows that the automated quality measures for each remote sensing measure are capable to differentiate between critical (orange) and good (green) measurements as well. The quantitative comparability of products from different satellite sensors is demonstrated in figure 12 b) for Lake Constance and figure 12 c) for a much smaller Lake (Walchensee) with consistent turbidity measurements from MERIS and Landsat 7, which match well with the in situ measurements where available. Figure 13 a) shows again the long term consistency of satellite derived Chl a and an excellent match with in situ measures for Lake Müritz.

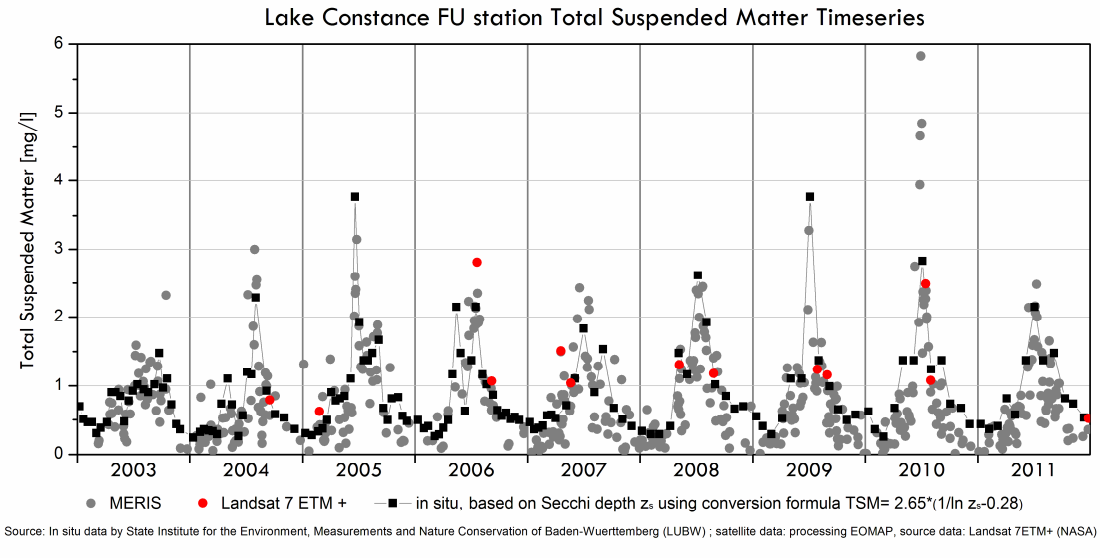
Still problematic with respect to Chlorophyll a are humic lake types as in Finland even with spectrally high resolved sensors such as MERIS or upcoming Sentinel 3, usually Chlorophyll is overestimated here (figure 13b). Spatially higher resolved sensors such as Landsat 7, 8 or Sentinel 2 retrieve good and harmonized results for turbidity and related suspended matter, but have limited capabilities to derive Chlorophyll independently. The physical measure that can be derived independent on turbidity is organic absorption. Combining the organic absorption with the satellite derived turbidity, still an estimate of the maximum expected Chlorophyll concentration seems feasible for the spatial highly resolved sensors (figure 13 c).

Significant sources of differences between in situ and EO measures are also the inter-comparability of the in-situ measures itself and the differences in the methodology (sampling size, vertical depth, water sample preparation, in situ methodology). One essential outcome of the validation exercises was the fact, that the physical measures of the EO products in terms of spectral absorption and scattering is harmonized over all satellite sensors on an pan-continental scale, if the applied algorithms and processing chains are capable to process the data based on harmonized physical interpretation and correction.

a)

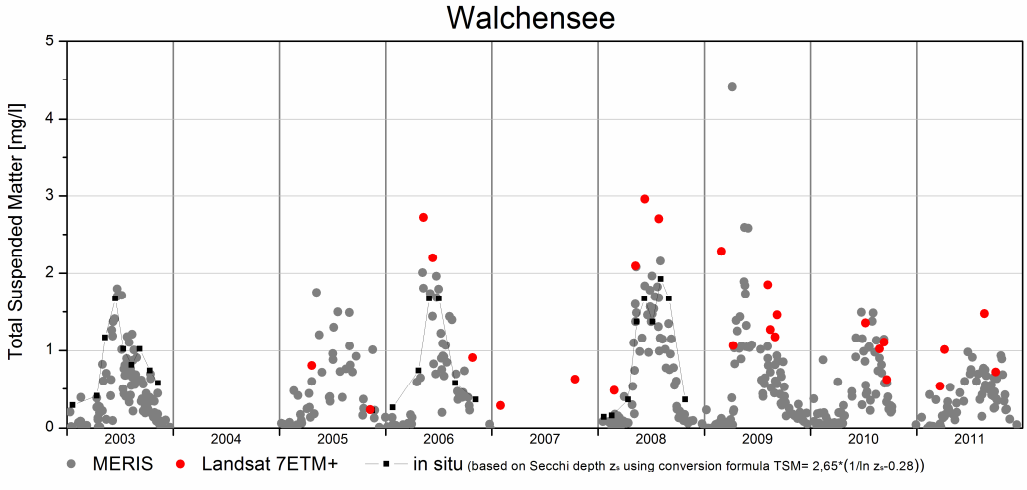


b)



Source: In situ data by State Institute for the Environment, Measurements and Nature Conservation of Baden-Wuerttemberg (LUBW) ; satellite data: processing EOMAP, source data: Landsat 7ETM+ (NASA)

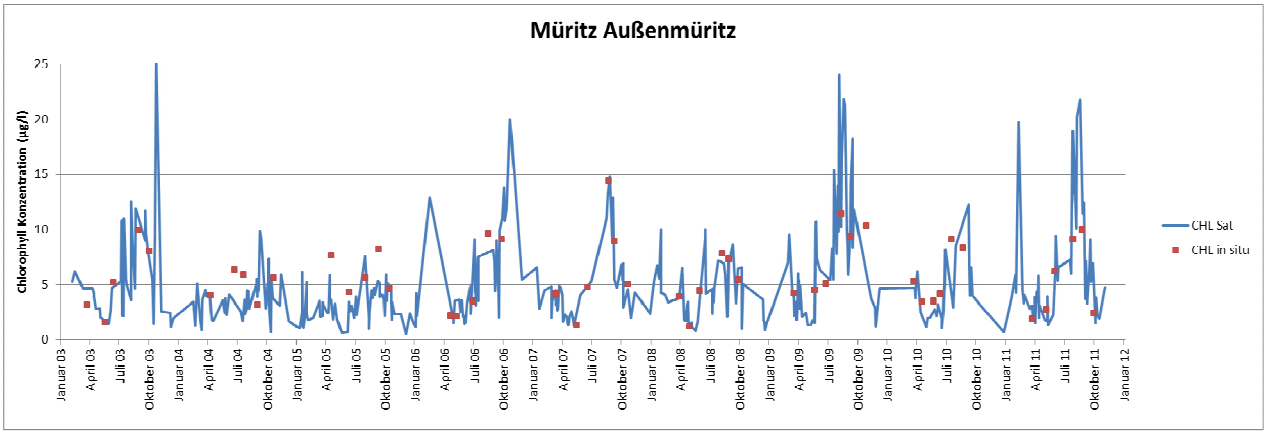
c)



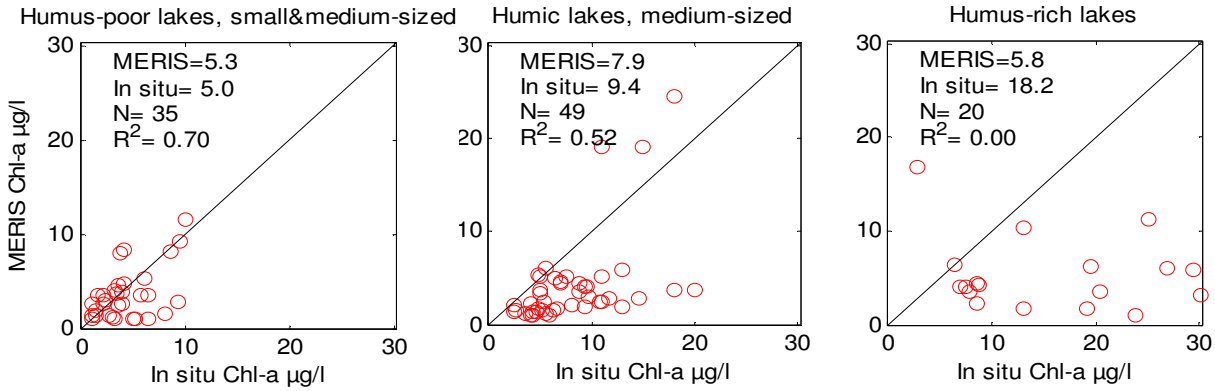
Source: In situ data by the Bavarian Environment Agency (LfU) ; satellite data: processing EOMAP, source data: Landsat 7ETM+ (NASA)

Figure 12: Time series of Chl-a and TSM from satellite data and in situ data at the FU station Lake Constancea and Walchensee. In situ measurements were kindly provided by BOWIS –Lake Constance Water-Information-System provided by IGKB and LfU

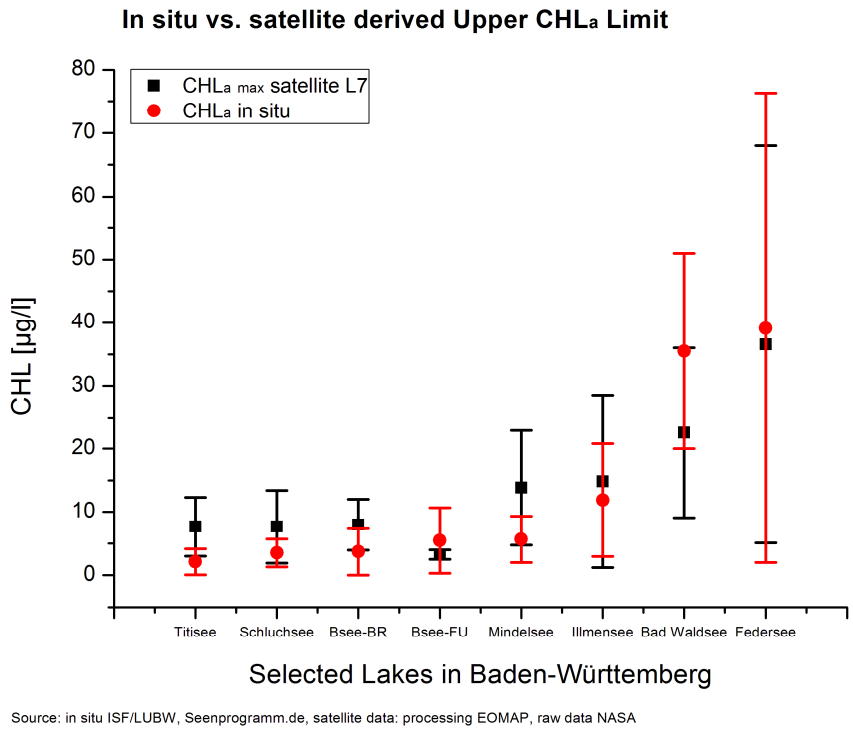
a)



b)



c)



Source: in situ ISF/LUBW, Seenprogramm.de, satellite data: processing EOMAP, raw data NASA

Figure 13: Validation results of time series of Chl-a Lake Müritz with MERIS, different lakes types in Finland with MERIS and Chlorophyll maximum in small lakes from South Germany with Landsat

Lessons learnt in the FRESHMON product validation are that important issues have to be taken into account when comparing satellite and in situ measurements are:

- Qualitative temporal trends and dynamics are more in focus than quantitative comparisons of values when generated with different methodologies. This is mainly due to the lack of simultaneous match-ups.
- Possible time coincidence of the measurements in areas with highly variable conditions, e.g. rivers or river inflows, is highly recommended when comparing same day measurements.
- Location of the sampling stations, e.g. near the shore, can influence the results.
- Different sampling depths occur in most cases when comparing satellite with in situ measurements.
- Feasibility check of suitable images (turbidity, atmospheric conditions) for water depth processing.
- Pixel wise quality control (the quality levels of data points in result images are indicated with e.g. different symbols) of the satellite product plays an important role for the validation.
- Temporal vs. spatial resolution needs to be demonstrated to the users and the advantages/ disadvantages needs to be discussed especially with respect to their requirements.
- Further aggregation of products may bring the products closer to the requirements of the users and the validation results also are less sensitive to single pixel to point comparisons.
- In situ data which would follow the recommendations for validation purposes are not always available. Routine in situ data is often acquired with different focus. Nevertheless, our validation activities show that it is possible to compare the two data sources in useful way.

1.5.5 Product Quality Assessment

The product quality assessment process was defined considering the users and technical requirements, the existent validation procedure of the project partners and by referring to the MarCoast Validation Protocol (2006 and 2010).

The FRESHMON validation procedure mainly relies on three core elements: the service providers, the users and the validation team. Both, the service providers and the users will compile and provide a validation report with each delivered service and product. Subsequently, the validation team reviews the reports and generates a summary service utility report. A template for the service provision report and the user feedback and validation report is attached in *D55.1*. For the FRESHMON validation procedure see Figure 14.

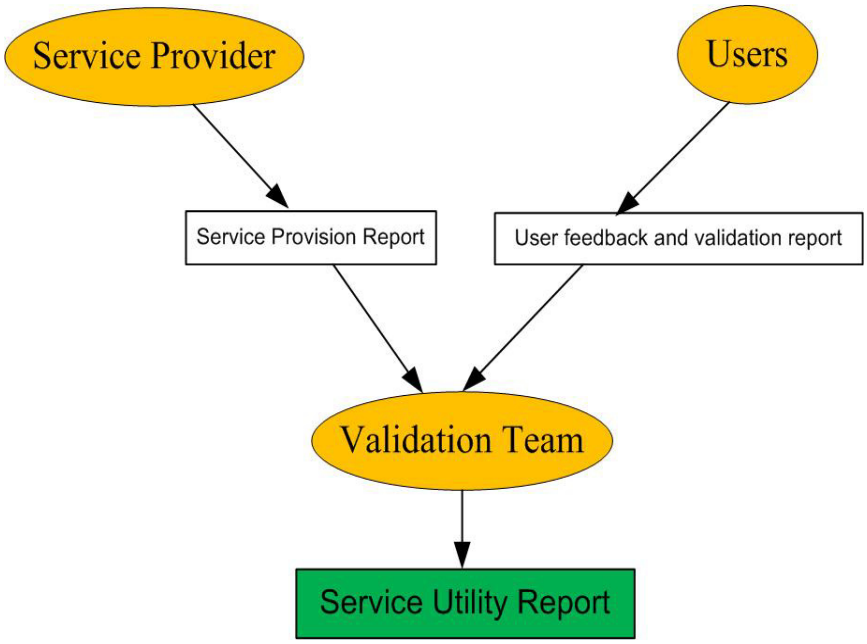


Figure 14: FRESHMON validation procedure

1.5.6 CORE service validation

The aim of WP 5.6 was to compare and analyze the potentials of existing CORE services to be used as input for the FRESHMON services. In the deliverable 56.1 several CORE services like Geoland2 and MyOcean are investigated referring to their water related products. As a summary, the Core Services do not currently provide data that could be used as input for FRESHMON services and products or act as parallel services. The main problems with the current services are lack of suitable data (e.g. product types, area coverage, and/or validation) with sufficient spatial resolution (relative to FRESHMON requirements). My Ocean products can be used in frames of feasibility studies, like Secchi Depth 1km for Baltic Sea.

Figure 15 demonstrates the differences of the spatial resolutions.

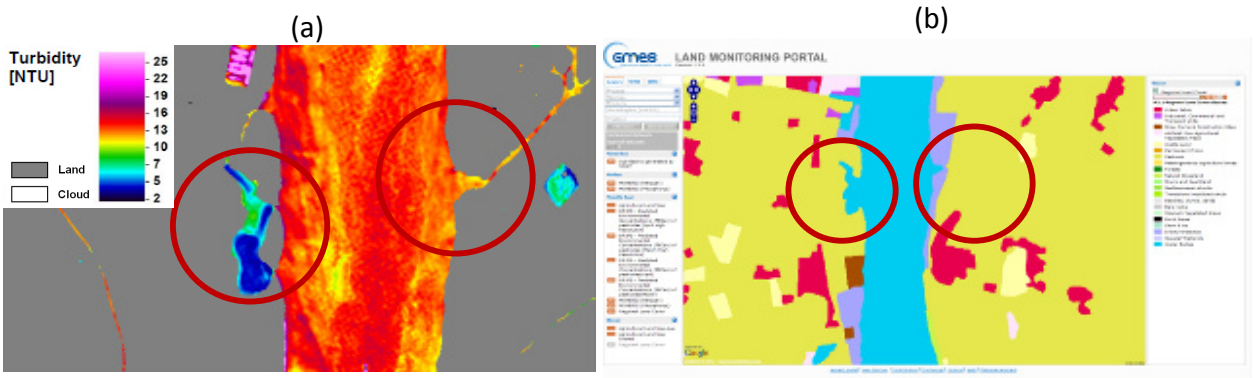


Figure 15: Comparison of the spatial resolution of the land-water masking of (a) a RapidEye product delivered to the FRESHMON user showing a more detailed masking and (b) the Water Bodies layer of the regional land cover data available in geoland portal of the same area (http://www.land.eu/portal/)

Furthermore, due to the recent failure of ENVISAT, no new Land Core Service water quality products are expected. The Sentinels, once they are launched, will change the situation.

1.6 WP6 Dissemination and Service Network Evolution

1.6.1 User training

In the frame of FRESHMON special user trainings were undertaken to improve the understanding and expertise of users in using EO products, but also to achieve feedback how to deliver and adapt EO products and services in order to get them applied. Several user groups in Germany, Finland, Netherlands, Sweden, Switzerland, Austria, Liechtenstein and Estonia, covering national, federal and local agencies responsible for lakes, rivers and coastal zones were consulted (see *D61.1*, *D61.2*, *D61.3,* see Table 9).

Table 9: FRESHMON main face-to-face user trainings

Date	User	Involved Partners	Main Topics
2011-03-25	Federal Waterways Engineering and Research Institute (**BAW**) and German Federal Institute of Hydrology (**BfG**)	BC and EOMAP	Application of remote sensing for the BAW applications
2012-03-30	Marine Research Centre of the Finnish Environment Institute (**SYKE/MRC**)	SYKE	User needs discussion, product discussion, possible improvements
2012-04-18	Bavarian Environment Agency (**LFU**)	EOMAP	Project Introduction, Validation, Format discussion
2012-08-15	Swedish Agencies via Brockmann Geomatics	BC	Presentations of processing steps, final products, discussion about integration into daily monitoring work of Swedish Users
2012-09-12	**Deltares**	WI	Discussion about products, SLA and in situ data for tuning
2012-10-05	**Cornell University**	WI	In situ data and product discussion
2012-09-12	Freshwater Centre of the Finnish Environment Institute (**SYKE/FWC**)	SYKE	User needs discussion, product discussion, possible improvements
2012-09-26	Marine Research Centre of the Finnish Environment Institute (**SYKE/MRC**)	SYKE	User needs discussion, product discussion, possible improvements
2012-02-11	Marine Research Centre of the Finnish Environment Institute (**SYKE/MRC**)	SYKE	User needs discussion, product discussion, possible improvements
2012-11-13	**ISF-LUBW**	EOMAP	Time series analysis, validation, harmonisation
2012-12-20	Bavarian Environment Agency (**LFU**)	EOMAP	Validation results, delivered products, upcoming tasks
2013-02-08	German Federal Institute of Hydrology (**BfG**)	EOMAP and BC	Delivery, Validation, Monitoring, case studies
2013-03-18	Federal Waterways Engineering and Research Institute (**BAW**)	BC and EOMAP	Product Application, Data formats, further cooperations
2013-06-17	Internationale Gewässerschutz-kommission für den Bodensee (**IGKB**)	EOMAP	Project Introduction, Validation, Application
2013-11-06	**BfG**, **LfU**, **LUBW**	EOMAP	FRESHMON workshop: Comparability of EO vs. in situ methods, data integration

In general, the main intentions of the user training activities were to demonstrate different product formats and analysing tools in order to improve the integration of earth observation (EO) data into the daily work of the user, the development of concepts and potential application fields for further user products and the demonstration and discussion of validation results.

One workshop occasion was the project meeting, organized by SYKE in Helsinki, Finland, on the 7th October 2011. The Finnish companies, governmental institutes and other project partners were invited and the FRESHMON project activities were presented.

Another example was the FRESHMON workshop on "Pan-European COPERNICUS Inland Water Quality Monitoring Services" on 6th November at the European Space Solution in Munich. After short introductions into methods, formats and application we discussed with three agencies the comparability of the EO products and their in situ methods. We gained deeper insights in the required data format and data aggregation, e.g. as a starting point an annual mean value has been defined as suitable for the classification of the ecological status. The agencies expressed their high interest in the products and related services. Accordingly, we have been organizing follow-up meetings and service preparation for several authorities.

Further fruitful discussions and user specific product design were carried out with e.g. the German users.

As one result the users now consider EO products as a complementation of their classic water quality monitoring measurements in form of an auxiliary tool with several advantages. Further, in course of the user training activities, new products as well as refinements to existing products have been developed and user specific case studies have been conducted. These improvements support the integration of the EO products in the working routines of the users. Concrete steps for further cooperation have been discussed and planed with the users, partly only feasible in follow-up projects.

In sum the confidence and acceptance of the EO products increased with the user trainings conducted, a better understanding of the user requirements was achieved.

1.6.2 Service Utility Assessment- Summary Report

A summary of all Service Utility Reports (WP 62) provides an overview of how all FRESHMON products were received and what the most important lessons learnt include.

In all three phases of the project, the delivered products and services were reviewed by the user. In total, fourteen organizations filled out the questionnaire. Twelve out of these were happy with the Freshmon products and the possibilities of this data source.

Benefits of the FRESHMON products

The most mentioned and/or most important benefits of the FRESHMON products were:

- The satellite retrieved water quality products can be successfully used for assessment of distribution patterns as effect of wind, currents, river discharge etc.
- Because of successful visualisation of spatial patterns, the data source is valuable to analyse the effect of man-made constructions such as dams, ecological processes such as clearance of the water due to filter-feeding by mussels and for decision-support, such as to decide on the best locations for in situ monitoring stations.
- The use of satellite-based products (of some of the sensors) contributes to a much higher temporal resolution than conventional monitoring. However, some sensors with high spatial resolution have too low temporal resolution for monitoring. Data from these sensors is valuable for the analysis of patterns though.
- For example, in Finland the extent of monitoring can be improved, because there are so many lakes that it is not possible to cover all with conventional monitoring.
- The FRESHMON service provides an interesting alternative to available ocean based algorithms and is interesting for developing other developing freshwater-based tools that are not yet available.

Only three user organisations were not convinced about the FRESHMON services. One user (in phase 2) expected products that can technically not be delivered from satellite data; this service was therefore not continued. Another user that was not convinced about the products (provided in phase 3) was not satisfied with the amount of available data (few images, with many clouds and quality flags). This service will probably be continued after the end of the project, based on more products and more validation. In addition, a user denied the cooperation with FRESHMON as the products did not deliver sufficient parameters such as species types or vertical resolution.

Product Quality Assessment

The evaluation of the quality of the products varied a lot between product and users and is therefore hard to summarise. Some users concluded that the provided data agreed very well with in situ data, others found large discrepancies and there were also users who do not have access to in situ data and could not do a proper evaluation. Also on the resolution of the maps the opinions were scattered. Some generally points that can be made:

- Turbid and highly absorbing waters (e.g. Finnish waters containing high concentration of DOM) are difficult to map
- Land/water borders, especially in regions with tidal flats and/or islands and/or bottom visibility are difficult to map. This makes small lakes the most difficult projects.

- When there is more in situ data available for tuning and validation, generally the quality can be improved. Also, the users are more convinced when there is more in situ data the products compare to.
- When no accurate estimates of a parameter can be made, consider mapping “high” - “low” instead of suggesting accuracy by including a legend showing mg/1.
- A dedicated error product and/or flagging schema can assist the user to understand which pixels contain reliable data, and for which pixels the circumstances were difficult and the provided data should be handled with care.
- Temporal and spatial coverage is often checked as a large advantage in comparison with regular monitoring. Nevertheless, higher temporal and spatial resolution is always welcome.

Service Quality Assessment

Next to the quality of the products, also the quality of the service was evaluated. The summary of the answers received from the users is shown in Table 10.

Table 10: User feedback to Service Quality received during the project

	1 (very positive)	2	3	4	5 (very negative)
availability	4x	10x	2x		
accessibility	6x	7x	1x		2x
Readability/ comprehensibility/ reliability	6x	6x	3x	1x	
feedback possibilities	6x	8x	2x		

Comments with regard to the service quality concerned two main subjects:

- File format issues (which generally could or will be solved in the next delivery);
- Data availability. Some users indicated to want more data. In some cases this could or can be solved, in other cases the low availability is due to the overpass frequency of the satellite sensor and/or clouds and more data is simply not possible.

Possible improvements and new products

After evaluation of the deliveries, the users were asked to suggest improvements. Several of these could directly be implemented in the next deliveries. However, there were also suggestions made that are technically impossible. Often-mentioned improvements related to:

- Understanding of the data: including of a manual, summary and including training. These issues

are solved or will be solved in next deliveries.

- Inclusion of error products. These issues are solved or will be solved in next deliveries.
- Improved flagging for land, clouds, bottom visibility, macrophytes etc. Some of these issues could and have been solved. Others, like the flagging of below-water growing macrophytes, could not be solved. For cases where we know that flagging is not perfect (such as the known cloud shadows), it is best to include this information in the user training, so they learn how to recognise these issues.
- Longer-term datasets, larger part of the year and generally: more data.
- EO products should be added to existing water quality data bases when possible, so users do not have to look at them separately
- In situ measurements provide both a means to tune satellite data and a source for validation and are therefore important for evaluation of the FRESHMON services. In all user assessments it has been mentioned that “more in situ validation” is welcome.

The users themselves were happy to contribute in situ data for validation or to assist the provider in validation activities when possible (see e.g. D54.2 Radiometric and in situ measurements of the ground truth for assessing the services). Some of these cooperations between user and provider for validation activities are expected to continue in future.

Last, we asked the users what other inland water products they would be interested in. Some indicated very specific products, for example aggregates of the already delivered products. Also, products that were already in the FRESHMON portfolio (but were not delivered to that user) were suggested. The completely new products that were suggested are:

- Sediment distribution as combined product of optical and radar sensors.
- High resolution Chl-a mapping
- Surface temperature maps
- Bottom mapping, or, as more specifically mentioned by another user: underwater and coastal vegetation and availability of sandy shores (for mapping and modeling coastal reproduction habitats of fish).

1.6.3 User expansion

The consortium partner undertook manifold activities to increase the public awareness for FRESHMON services, to generate promotional materials and expand the user community for FRESHMON services.

The consortium prepared and distributed

- a policy brief for *Downstream services under the GMES framework* (see delivery *D63.1*)

- a position paper how to push and exploit GMES and EO services to derive maximum benefit for Europe's social-economy, with respect to the different roles of publicly organizations, commercial service providers

We investigated significant efforts to attract new users with intelligible messages e.g. on the new FRESHMON web portal, the policy brief, in worldwide presentations by the partners. FRESHMON was ongoing promoted to new users in Europe (e.g. Cornell University) or worldwide (e.g. World Bank). We use and prepare the FRESHMON visibility in various platforms to get new users attracted, so the FP7 GRAAL platform (GMES for Regions: Awareness and Access Link), the Bavarian Research Alliance, the GMES Masters competition to develop new applications for high resolution water quality products (see http://www.gmes-masters.com/winners/aquamap).

To increase the public awareness the FRESHMON consortium presented the project on various user and scientific conferences (see Table 11). With the oral and poster presentations the application of the monitoring of inland waters with earth observation was disseminate to both the researchers, service providers and (potential) users.

Table 11: Main Conference Participations and other FRESHMON representations

Date	Conference	Involved Partners	Activity
2011-02-17	Workshop on Remote Sensing of lakes, Norwegian Institute for Water Research	SYKE	Presentation and BEAM training
2012-01-24 – 2012-01-26	WISER Conference, Tallinn	BC	Poster Presentation and User contacts
2012-02-28 – 2012- 02-29	SpaceEU, Brussels	EOMAP	15 min presentation and 30 min round table discussion
2012-03-01	Haus der Forschung Opening	EOMAP	Booth with FRESHMON materials
2012-04-23	Sentinel-2 Preparatory Symposium	SYKE, BC	Oral presentations and papers
2012-04-22	EGU General Assembly, Vienna	EAWAG	Poster presentation
2012-09-24	DGL conference	User ISF, EOMAP input	Oral presentation: Detection of spatial variability of chlorophyll: combination of satellite data and ground truth
2012-10-09	3rd European Large Lakes Symposium	EOMAP	Poster presentation, inputs for presentation of ISF
2012-10-15 - 2012-10-19	Sentinel-3 OLCI/SLSTR&MERIS/(A)ATSR WS	BC, SYKE	Poster on "Requirements on Pre-processing for Retrieval of Water Quality of Lakes with Medium Resolution Data" and "EXPERIENCES IN MONITORING FINNISH LAKES WITH MERIS"

Date	Conference	Involved Partners	Activity
2012-11-15 – 2012-11-16	2nd FP7 Space Conference	WI	FRESHMON representation
2013-04-07 – 2013-04-12	European Geosciences Union Vienna (EGU)	EAWAG, LUBW with support of EOMAP	Oral presentation and poster(EAWAG), Common poster presentation User-Project Partner
2013-07-04	Symposium for Freshwater Sciences Münster (SEFS)	EOMAP, BC	Organisation of a dedicated session; Presentations and poster
2013-09-09 – 2013-09-13	ESA Living Planet	BC, SYKE	BC: Poster presentation, company booth also presenting Freshwater topics SYKE: Poster
2013-09-09 – 2013-09-13	Annual conference of the German Limnological Society (DGL)	EOMAP	Oral Presentation and poster presentation Pan-European Water Quality Atlas

In addition, in phase 2 two articles for “Window on COPERNICUS (former: GMES)” were prepared and have been published in December 2012 (available under copernicus4regions.eu). The user portrait of the user Dr. Norbert Winkel from Federal Waterways Engineering and Research Institute (BAW) highlights the advantages of the earth-observation for their river engineering. The success story about the FRESHMON describes the project in general and two map examples were given.

Also located in the work package 63, an update of the Policy Brief, created in phase 1 was envisaged. To enhance the awareness of the FRESHMON services in the user groups, we decided to prepare a FRESHMON flyer disseminated at conferences and workshops. The FRESHMON flyer covers the range of the products and services as well as user comments to the provided delivered products, underlining the advantages of the Earth- observation-based water quality products. Several applications of the service, like supporting the Water Framework Directive reporting or impact assessment are highlighted and underpinned with product examples (see Figure 16).

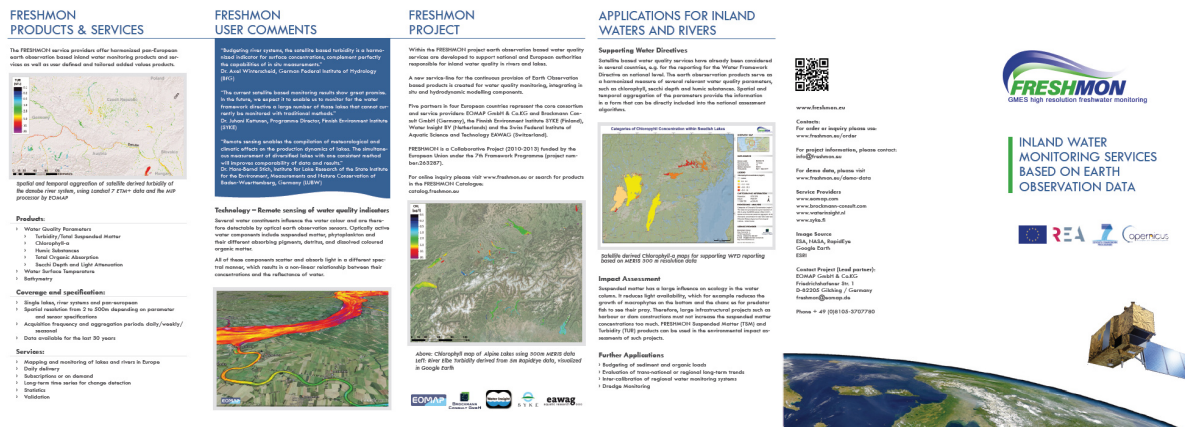


Figure 16: FRESHMON Flyer introducing products & services, potential application and with dedicated user comments

1.6.4 FRESHMON Web Portal

The web portal is the 'visible' part of the service provisioning infrastructure, interfaces (WMS, WCS) and project information. The site can be found at http://www.freshmon.eu/. A new design has already been made to improve the tangibility of the FRESHMON services, the user friendliness and usability, see Figure 17.

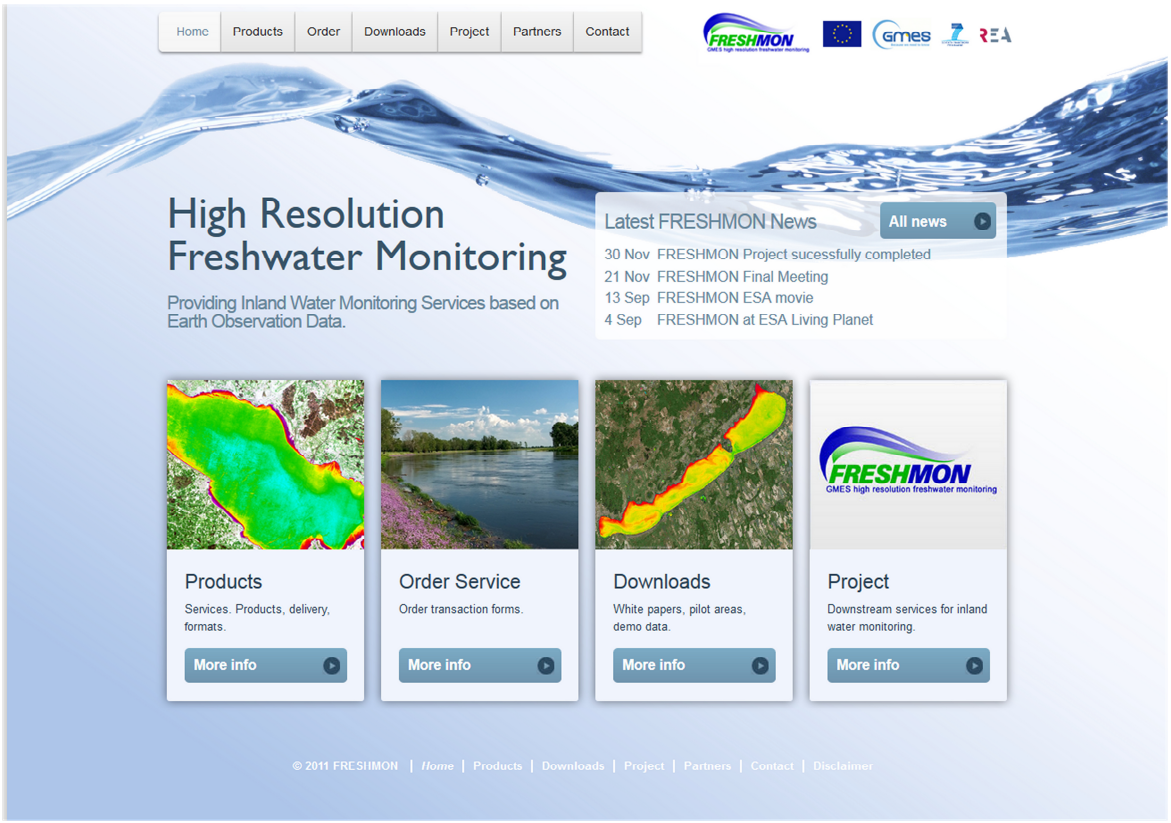


Figure 17: FRESHMON Web Portal

In addition to general information on the project and partners, it offers download of sample data sets, a link to the FRESHMON catalogue, containing meta-data on the products that were created within FRESHMON, and an enquiry form.

The enquiry form lets the user specify an area and time period of interest, parameters of interest and preferred delivery format. The enquiry is forwarded to the service providers who will come back to the user with an offer.

The web page will be maintained also after the lifetime of the project.

1.6.5 Service Portfolio Definition

With the D65.1, submitted in December 2011, the FRESHMON service portfolio was illustrated and visualized with product sheets. The descriptions of the products for dissemination and marketing purpose range from several water quality parameters to the mapping of water depth. The product sheet s are available on the FRESHMON web portal (FRESHMON Service Portfolio) and are part of the standard delivery of the FRESHMON services

The product sheets generated in phase 2 have been extended according to the recommendations given in the review meeting with additional information about the different resolution and application of the products. Also, the service dedicated to the WFD reported has been added to the portfolio, see Figure 18.

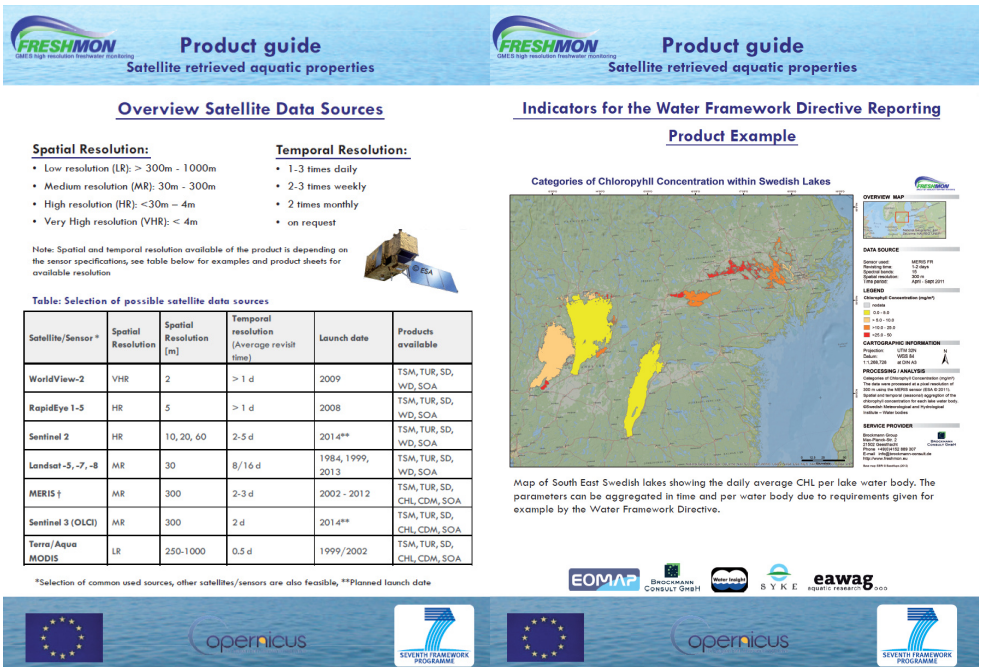


Figure 18: Example of updated Product Sheet with available resolution classes and service example for WFD

1.6.6 Service Network evolution

In phase three of the project, one main focus was on the service network evolution. Next to user oriented meetings, the FRESHMON consortium elaborated a White Paper for a Pan-European Inland Water Quality Monitoring Service (together with other Inland Water projects). After describing the policy framework, we highlighted the capabilities of the earth observation based water quality monitoring as a harmonized, trans-national and Pan –European service in close connection to the requirements in the Water Framework Directive and the Blueprint COM(2012)673. It also includes a detailed description of the offered services/products and a first estimation of costs. We presented this

at the 2nd Workshop GMES/Copernicus In-land water services meeting in Brussels on the 20th June 2013 to representatives from EC, EEA, DG ENV and DG ENTR. The next step will be to iterate this proposal in the DGs and EEA as well as to inform the National Copernicus committee members and Member states WFD authorities on the proposed services. This is expected to take place until end of 2013.

D66.1 Business Model deliverable (confidential, not public available) summarizes the results of the analysis of the market situation and the received experiences throughout the project. Three different service lines have been delineated taking into account the experiences and the analysis of the market situation: (Obligatory) Monitoring, On-Demand and Off-the-shelf services. The different aspects of a strong and weak collaboration of the FRESHMON consortium have been investigated using a SWOT analysis. The consortium decided to follow the weak cooperation level for now, instead of a high financial and personnel consuming cooperation.

However, a first step towards a stronger cooperation is done with the White Paper proposal of a Pan-European Water Quality Service. If this service will come into reality, we would have the opportunity to take further steps into the direction of closer cooperation and submit a common proposal.

A special situation represents the view of the government institute among a group of private EO service providers. For them, the future activity should be performed with funding from more permanent sources such as Copernicus instead of individual research projects.

2 Socio-economic impact and wider societal implications of the project

Tools to evaluate the ecological status of inland waters in the past and the future are of significant socio-economic relevance worldwide. The demand and the challenge to develop and maintain affordable methods to retrieve comparable, harmonized status information on regional, trans-national and pan-continental scale is well known to the European Commission. The urgent need on water quality information is also day-to-day apparent in a majority of counties worldwide. The quality and distribution of drinking water, waste water, water for agriculture and industries, load of organic components and nutrients, sediment loads for the river construction and navigation are all topics with direct socio-economic impact. The technologies and monitoring capabilities developed in FRESHMON will significantly contribute with monitoring in the present and impact evaluation through comparisons with the status up to decades ago. Recent projects and inquiries from water suppliers, dam operators, water agencies and intergovernmental bodies such as World Bank as well as the demand of individuals for water quality in various areas of life proof the expected socio-economic impact.

Several federal and state authorities and users now understand the benefits and request the service providers to integrate paid EO services into their field of duty. We define this transition of a project

driven approach to a user uptake of services as the major indicator of a successfully project and the expected socio-economic impact. Accordingly, the service providers started now in commercial driven invests to sustain and expand the developed capabilities. A harmonized, Pan-European Water Quality Service is now capable to serve the European stakeholders and is currently discussed at the EC and member states on base of the Whitepaper proposing satellite based inland water monitoring services.

3 Main dissemination activities

The main objective of the dissemination activities of FRESHMON were to build-up user awareness, acceptance and adoption of the FRESHMON services by active promotion.

In order to disseminate the developed services, products and results, the FRESHMON consortium

- actively participated in several user conferences with common user-project-partner oral presentations and posters
- created promotion materials, like FRESHMON Service Portfolio, FRESHMON Flyer, FRESHMON Policy Brief, FRESHMON Position Paper (all available on www.freshmon.eu/downloads)
- published several articles in scientific and public press
- generated in cooperation with the German Aerospace Center and ESA a FRESHMON movie (available on www.freshmon.eu/downloads)
- contributed to the White Paper on COPERNICUS Inland-Water Services: Pan-European Inland Water Quality Monitoring Service (available upon request)
- promoted FRESHMON services and products in various occasions like exhibitions, general community assemblies etc.

4 Exploitation of results

In the frame of FRESHMON, new capabilities were developed to monitor freshwater systems with improved technology, harmonized products and metadata, to evaluate and aggregate products, and to serve clients with EO based water quality services. Users were trained, results disseminated and trust into the new information technology was created.

As part of the scientific exploitation, the FRESHMON outcomes are currently taken up by various research projects to further improve the EO technologies (e.g. the EC FP7 projects GLaSS and INFORM, or national projects and EPFL Lausanne established a new remote sensing group).

The service infrastructure established by FRESHMON shall be maintained to attract and guide new users, and serve them from the partners of the consortium.

Most relevant, the commercial exploitation of the project outcomes accelerated significantly with project completion:

- Service providers register and follow an increasing number of requests from various client groups (water agencies and authorities, commercial water suppliers, dam-operators, governmental GIS and GEO-IT-infrastructure providers, …) to provide EO services.
- Service providers change the production from project driven to trans-national off-the-shelf production, which allow a very cost-effective and flexible access to harmonized high-resolution products for clients. We expect that his paradigm change will significantly decrease barriers to use EO based services and increase the exploitation. As result of this off-the-shelf production, e.g. EOMAP launch the web shop to access to daily updated water and bathymetry products on trans-national level in February 2014.
- Service providers work now with several water agencies on the conception to integrate the new EO monitoring capabilities into the governmental workflows, including the creation of customizing and aggregation the requested information for reporting.
- The consortium also support the European Commission and the national stakeholder to setup a Pan-European Copernicus Water Quality Service for the EC member states.
- The upcoming Sentinel-2 and 3 satellites will dramatically foster the exploitation of FRESHMON into various vertical sectors, if the EC supports

  a) data policies and the suitable technical infrastructures to access the satellite data, that will allow an unlimited, operational fast and efficient access and

  b) rules with transparent separation between downstream services and public core services (e.g. in terms of provided resolutions), to guaranty the exploitation of commercial driven investments into the sustainable technology and market development.
- Pushed by a free market economy, we expect a worldwide exploitation of the new technologies due to the significant demand of a large number of non-European countries on harmonized and area wide water quality information. E.g. EOMAP already invested in non-European affiliates to exploit the FRESHMON supported water quality monitoring technologies in Asia, Australia and America.