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Abstract (for dissemination)	Final report which comprises a final publishable summary; a plan for use and dissemination of foreground and a report covering the wider societal implications of the project
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PROJECT FINAL REPORT

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[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.
[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

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1. Final publishable summary report

1.1. Executive summary

Measuring the optical properties of water bodies (as indicators of, e.g., sewage impact, dissolved organic matter, sediment load or gross biological activity) is a way to assess their environmental status. The Citclops project, in 2012-2015, developed systems to retrieve and use data on natural-water colour, transparency and fluorescence, using low-cost sensors combined with contextual information, taking into account existing experiences (e.g., Coastwatch Europe, ECSA's Projects, data, tools & technology working group and CSA's Data and metadata working group).

People are now able to acquire water-quality data taking photographs of the water surface on ferries or other vessels, at the open sea or from the shore. Additionally, digital cameras for aquatic activities with extended sensing systems have been deployed as alternative resources for collecting data in a participatory way. All these data are automatically uploaded through a specific service (similar to Dropbox, or Google Photos Back up & sync), processed and archived remotely, and resulting information is accessed through a webpage or a mobile application by end users.

These end users include: decision makers (e.g. local administrations and harbour masters), who can use the information to improve the management of the coastal zone and specific activities such as dredging; the aquaculture and shellfish industry, which is highly dependent on early algal bloom detection; citizens, who can source and provide water colour and transparency information, which can play a key role in enjoyment of recreational activities; educators for new geography and biology teaching; and researchers. Citclops developed a novel approach that embraces the expanding behaviour of citizens as information *prosumers* in social applications. By enabling citizens to carry out participatory monitoring based on low-cost devices, Citclops achieved two main goals:

- to expand the range of monitoring possibilities; and
- to raise the citizen engagement with environmental issues.

Engagement of stakeholders (science and technology researchers, decision makers, and society) in a *citizens' observatory* such as Citclops can be described as a process from initial stages of maturity (e.g., widespread water colour and transparency misconceptions) to more developed understanding. In the early stages, Citclops' researchers consulted stakeholder communities as they planned, designed and started to implement the citizens' observatory. As Citclops development process evolved, stakeholders took a more active role, participating in the citizens' observatory's structure and management, and sometimes negotiating with Citclops's partners to ensure their specific goals and values were represented. Now at full maturity, Citclops shared management between project partners and stakeholders, and in some cases transferred management completely to local communities, with the citizens' observatory's managers only providing advice and consultation. It is critical to note that the participatory engagement of stakeholders was perhaps the most important component of the planning and development of Citclops.

Meaningful engagement depended on the ability of researchers to build a healthy, lasting and trustful relationship with stakeholders, including local communities. The approaches developed by Citclops were intended to define and develop this process of stakeholder engagement in the domain of natural-waters' monitoring; and Citclops's development can be summarised in a series of five steps: (1) understanding and engaging stakeholders; (2) getting started with stakeholders; (3) developing a participatory-science approach; (4) stakeholders acting as advisors; (5) developing co-management approaches. At each step towards increased stakeholder-engagement maturity, different techniques and tools are required. It is also important to note that it was assumed that engagement between stakeholders and Citclops was a progressive process that aspired to move stakeholders and communities that were initially less engaged to a situation in which they were highly engaged.

Finally, it is also important to note that a fundamental part of the empowerment of stakeholders is represented by finding suitable channels of information delivery. Key information channels were the Citclops Data Explorer [http://citclops-data-explorer.herokuapp.com/] and EyeOnWater [http://www.eyeonwater.org/] web portals. These were developed using innovative software architecture, data models (how to model observations and how to exchange data), standards (SeaDataNet, OGC, SensorML, development of more lightweight standards), data representation and visualisation, data sharing (how to provide data to GEOSS), semantic aspects and linked data.

1.2. Summary description of project context and objectives

1.2.1. New water-quality monitoring strategies and participation of citizens in environmental stewardship

Aquatic ecosystems are characterized by an extraordinary mix of human activities: e.g., tourism, fishing and industry (e.g., petrochemical plants and aquaculture). Given the often existing conflict of interests between conservation and exploitation, the fate of aquatic ecosystems is often a hot political issue; and the attitudes and values of stakeholders in environmental issues become an essential part of the stewardship of conflicting environments. New policies about environmental resources should have citizens' support and consider public attitudes from the beginning.

When managing complex ecosystems, this approach of seeking public support can run into some serious difficulties. No one can expect everybody to understand the whole tangle of ecological problems, and therefore it is important to ask how much of an educational effort is necessary. In general, public attitudes show a strong preference for protecting aquatic ecosystems or returning them to their natural status, and for recreational use. Given the state of affairs that exists in aquatic ecosystems, the word *natural* is open to a variety of interpretations. Scientists usually define it rather narrowly to mean *unaltered by human beings*. What the citizens mean usually is really *natural-appearing*. A great many people who value natural resources value them as something to look at. It will take generations of environmental education to create a general public understanding of the fact that the importance of nature and its processes goes far beyond scenery.

Part of this education and understanding can be realized through citizens' effective participation in environmental stewardship, and specifically, in the case concerning this project, in the **monitoring** of **coast and ocean waters**, which needs extensive data measurements, due to their highly complex dynamics, with high variability in space and time. Indicators of water quality/perturbation that could be measured by citizens in a **more or less voluntary, active or conscious** way include: *colour*, *transparency* and *fluorescence*. These indicators have to be contextualized through the use of geolocation and comparison with physicochemical, biological and meteorological data which are collected by monitoring agencies and research institutes and managed within the *European marine observation and data network* (EMODnet) [http://www.emodnet-hydrography.eu/] distributed data management infrastructure that is being developed and implemented in the framework of the *marine strategy framework directive* (MSFD), adopting INSPIRE provisions and SeaDataNet [http:// www.seadatanet.org] standards.

Colour and transparency in water have been measured for a long period: *colour* through the *Forel-Ule* (FU) scale (Wernand, M. R. and van der Woerd, 2010; 2011) and *transparency* through the Secchi disc (Boyce et al. 2010; Siege and Franz, 2010). *Fluorescence* (Moore et al., 2009) is important to detect particular substances, such as contaminants, but no long time-series exist in this case. The project aimed to develop low-cost systems (smart-phone cameras and quasi-digital optical sensors) to retrieve and use data on water colour, transparency and fluorescence, in combination with georeferencing, an Internet distribution platform and community involvement, inspired by existing experiences with other applications (e.g., Secchi Dip-In [http://www.secchidipin.org], Coastwatch Europe [http://www.coastwatch.org/], ECSA's Projects, data, tools & technology working group [http://ecsa.citizen-science.net/about] and CSA's Data and metadata working group [http://citizenscienceassociation.org/2015/11/12/introducing-the-data-and-metadata-working-group/]). This new approach would contribute to the global network of in-situ sensors necessary to monitor the environment, complementary to the actions conducted in the *global monitoring for environment and security* (GMES) initiative. Collected data would be interpreted and resulting information delivered to **decision makers** to improve the management of the coastal zone; resulting information would be also delivered through mobile applications to **citizens,** to help them maximizing their experience in activities in which water quality has a role, and to **researchers**.

1.2.2. New technologies for data collection, interpretation and information-delivery systems

European water directives require member states to adopt standard monitoring procedures and sufficient sampling efforts. For example, the *bathing water directive* (2006/7/EC) includes the requirement that the interval between samplings cannot exceed one month. New technologies and methodologies involving citizens' participation, such as the ones developed by Citclops, can help to achieve the required monitoring standards.

Companies such as *Foursquare* [https://foursquare.com/] and *Facebook* [https://www.facebook.com/] proved the market and experimented with location-aware applications, but their most important function may have been to prepare society for a new way of communicating. These applications are training citizens to have access to knowledge of where everyone else is in physical space, shared through the Internet: geolocation and gaming technology are starting to be used to connect people in the physical world (see Figure 1.).

Figure 1. Foursquare let people have access to knowledge of where everyone else is in physical space.

Real-time social networking that can tag people's preferences will be surely used for marketing, but it can be used also in location-aware decision making and co-operative planning. In this sense, several initiatives, such as the ones mentioned earlier, have enabled the participation of citizens in the collection of environmental data with new technologies, complementing conventional programs and government-sponsored campaigns, which are sometimes being cancelled due to lack of funds.

1.1.1. Objectives

The **general project objectives** were to contribute to cover existing and future monitoring demands for coastal and ocean waters, building on existing initiatives and developing new ones. Citclops would address these objectives through:

(1) software and hardware development;

(2) applied research for defining an integrated network of in-situ observation systems; and

(3) basic research into earth observation applications and context-aware environmental-information delivery to target users.

Citclops would lay the foundations for a more efficient monitoring in a citizens' community setting, guaranteeing the financial sustainability of the project from a lab to market perspective. In addition, more competitive applications promoting sustainable management of the natural and human environment were proposed. To attain these objectives, the primary focus would be on advancing knowledge on the interactions among biosphere, ecosystems and human activities, and developing new technologies, tools and services in order to address global environmental issues in an integrated way.

Specific objectives of the project were:

- To enable citizens' participation in capturing environmental (water quality) data in coastal and oceanic areas through the use of existing devices, such as smart phones, as sensors, thus reducing the cost and effort of monitoring.

- To develop improved low-cost sensors and systems for monitoring water's colour, transparency and fluorescence, and use them in combination with georeferencing, an Internet distribution platform and community involvement.

- To provide recommendations in sectors such as energy, transport, fisheries, health and spatial planning, interpreting collected data through artificial intelligence techniques.

- To disseminate interpreted information to two kinds of users: citizens (individuals and associations) and policy makers (e.g., local administrations).

- To produce applied results, developing:

  (1) new applications for mobile devices;
  (2) friendlier and more flexible user interfaces;
  (3) social-networking capabilities to connect citizens and citizens' associations to policy makers;
  (4) a better support infrastructure.

1.2.3. Enabling citizens' participation in capturing environmental data

To encourage and enable citizens' participation in capturing water-column data, which was the most challenging objective in Citclops, a methodology has been adopted by Citclops's researchers to determine the types and level of engagement, including what the project wanted to ultimately achieve by engaging citizens/stakeholders. Techniques that were identified with earlier steps of stakeholder engagement provided a solid foundation for moving towards more sophisticated and mature levels of engagement. When progress was satisfactorily achieved within one phase, if there was an interest in moving forward, then the techniques associated with the next phase were reviewed and applied.

At each step towards increased stakeholder-engagement maturity, different techniques and tools are required. Some of these techniques and tools were more useful at some stages of Citclops development than others. For example, Citclops's *scientific advisory board* was involved during the understanding and engaging of stakeholders, and during the problem identification, but engaging in a *cooperative management* approach was not important to focus on in the early stages, when the *citizen observatory* (CO) managers were just beginning to work with stakeholders. At these early stages, it was more important to focus on *building trust* and *engaging stakeholders*. However, it is good to keep in mind that *cooperative management* became useful in the later steps of Citclops development.

It is also important to note that it was assumed that engagement between stakeholders and Citclops was a progressive process that aspired to move stakeholders and communities that were initially less engaged to a situation in which they were highly engaged, and ultimately took some level of responsibility for managing the CO. It was also assumed that some Citclops's researchers who had worked with mature marine-monitoring techniques already, could provide a solid foundation on which to build a mature CO in terms of stakeholder engagement. As the types and levels of stakeholder engagement became more complex and responsive to management needs, so did the monitoring and decision-making tools and frameworks required for making multi-stakeholder participatory decisions. In fact, the Citclops CO picked and chose the type of engagement it wanted with different stakeholders at different times, so the model used in the project was not always a progression, but rather provided a range of possibilities for engagement.

1.3. Main S&T results/foregrounds

Citizens, decision makers and researchers played a central role in Citclops's architecture's design. Citizens, by enabling their personal phones as smart information gateways responsible for collecting, processing and forwarding sensor data, became active agents in environmental monitoring. To achieve this, citizens have been provided with a set of tools favouring their engagement and fulfilling their requirements. A prominent example of engagement with stakeholders was the development of an app so that end users can collect data on the colour of natural waters: the **"EyeOnWater - Colour" app**, available in the Google Play Store and in iTunes (see Figure 2). Measurements are made by comparing the captured image from the smart-phone camera with:

(1) the digital version of a Forel-Ule scale;
(2) the output of an image-processing algorithm; and
(3) typical colour values coming from satellite's remote sensing.

Other apps have been developed so that end users can collect data on the transparency of natural waters (KdUINO Remote Control) and on its fluorescence (AppLED and FluorescenceApp). Additionally, and importantly, all these data have been processed and the resulting information was made available to the public through the **Citclops Data Explorer**, an innovative visualisation portal.

These main achievements have been possible thanks to significant intermediate results, which will presented in the rest of this section.

1.3.1. Crowdsourcing technologies for the monitoring of the colour, transparency & fluorescence of the sea

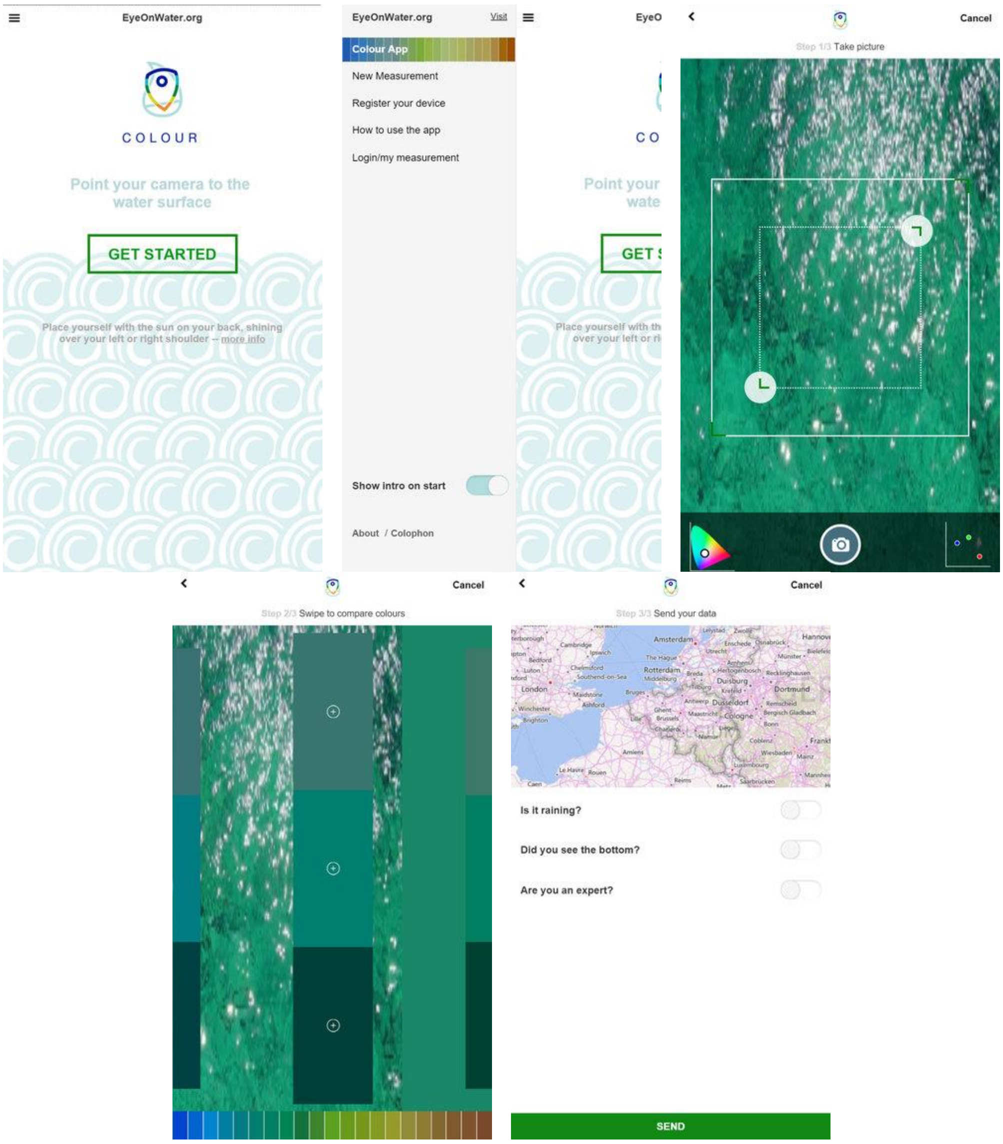

Figure 2. The "EyeOnWater - Colour" app

This section describes citizen-science technologies developed during the project for the monitoring of the colour, transparency and fluorescence of the sea. The objectives of this development were to define, develop and deploy hardware and software prototypes of citizen-science technologies to obtain optical data, and to validate the proposed sensing systems and measurement methodology through pilot studies with selected volunteer communities. Quality control methods were also developed in tandem with the development of the citizen-science technologies.

A monitoring system that provides good spatial and temporal coverage at low cost would be a vital contribution in order to improve understanding and enhance managing practices of the dynamic aquatic environment of inland and coastal waters. This can be partially realized through citizens' effective participation in environmental monitoring through the use of existing devices, such as smart phones, as sensors (see Figure 2). Therefore, we have investigated if digital imagery from cameras in smart phone can be used for monitoring the intrinsic colour of natural water bodies(see Figure 3). To this aim, simple measures were introduced to quantify the spectral distribution of the water-leaving radiance; images were acquired as close to the water as possible, to ensure correct white balancing; and the white-balance setting was used to mimic the colour adaptation performed by human eyes.

Specific results include **algorithms to retrieve the FU index from images coming from smartphones**. In particular, a new algorithm to derive the Forel-Ule index from RGB images has been developed which resulted in a high-impact publication, where full details of the procedure can be found (Novoa et al., 2015).

Figure 3. A selection of images used for the determination of the intrinsic colour. Top four images correspond to North Sea waters. The rest of the images correspond to Dutch inland waters.

Results also include **algorithms to retrieve water light extinction coefficients from images coming from smart phones and from low-cost smart sensors**. The use of low-cost technologies to retrieve water light extinction or attenuation coefficients implies a more advanced processing of the lower-quality data collected by smart phones or smart sensors. Data were collected via dedicated field-work campaigns, carried in the Wadden Sea, and in locations in Spain (mainly in the Alfacs Bay).

Results also include novel **sensing buoys with low-cost smart sensors**. The objective was to develop a mooring system equipped with low-cost sensors to obtain irradiance measurements at different depths. The design of the buoys followed the *do-it-yourself* (DIY) concept, and the construction involved only inexpensive and easy-to-use components. Post-processing of irradiance data is used to deduce the attenuation coefficient. The idea is that information on the incoming light is collected by quasi-digital optical sensors that convert light irradiance measurements into frequency. With this conversion, it is possible to obtain integrated measurements of irradiance values near the water surface, reducing the measurement variability derived from the large light-fluctuations caused by focusing of sunlight by surface waves and variable sky conditions. The hardware part of the buoys, named KdUINO, is based on Arduino and includes an internal memory and a system for Bluetooth or radiofrequency communication. A KdUINO is shown in Figure 4. Buoy's results have been compared to classical oceanographic instrument's results in various scientific publications.

Another result is an **expanded sensory system for wearable underwater cameras**, with the aim to obtain irradiance measurements at different depths with an underwater camera. A device has been developed to record the light irradiance at different depths. The device has to be set on a camera which will continuously record while the diver changes depth. The system has to be used jointly with a diving computer so the depth can be recorded at the same time. The time of the video is automatically collected from the video itself.

Results also include a **new methodology and novel technology for fluorescence measurements**. A prototype to measure fluorescence with smart phones was developed and a smartphone adapter was 3-D printed. The internal flashlight has been used for excitation of fluorescence, while the internal camera records the signal.

Figure 4. One of the buoys developed by some teenagers recording data

Developing the new method and sensory system using mobile devices (such as smart phones or compact cameras with flash lights) with embedded imaging sensors and, when available, excitation light sources, included:

1) **the integration of external LEDs** to the adapter, for excitation of fluorescence: a blue LED for enhanced excitation power and hence stronger fluorescence signal; and a UV LED to include light ranges outside of the range of internal LEDs;
2) **the development of an algorithm to convert *red-green-blue* (RGB) images to fluorescence signal** and substance concentration.

More specifically, the **integration of external excitation light sources was accomplished by the incorporation of LEDs and a small electronics unit** to the smartphone adapter, resulting in the final prototype for a mobile phone fluorescence sensor (*SmartFluo*) (see Figure 5). The external LED can be triggered manually or by a short audio signal of 15 kHz, sent via the headphone socket. This allows a direct communication with the smart phone and hence the use of an app to conduct measurements.

Figure 5: Prototype for measuring Chl *a* fluorescence by means of a mobile phone adapter for fluorescence measurements (SmartFluo). A sample in a cuvette (3) is excited by means of a blue LED (2, 4) and recorded by the internal smart phone camera. The LED can be triggered by a manual switch or by means of a short audio signal through the headphone socket (source: Christopher John).

Another result is an **algorithm to retrieve water light extinction coefficients from underwater cameras**. This is part of a technique, called TrandiCam, which has been developed for any kind of divers, either scuba divers or snorkelers. A set of two square white plates, on which a black circle is drawn, is used. Two divers must be present: one to hold the targets and the other one to take the pictures. An instruction manual is delivered to all volunteers. The algorithm to process the images consists in:

1. Transformation of the picture into gray-scale image using the *contrast limited adaptive histogram equalization* (CLAHE) approach.
2. Computation of the best threshold to be chosen to convert an intensity image to a binary image using the Otsu's method. Conversion to a binary image.

3. Detection of the different objects in the picture and selection of the circles.
4. Confirmation by the user that they are the circles, or change of the choice of the objects, or removal of the picture if the correct circles cannot be found.
5. Estimation of the distance between each circle and the camera using a great angle approach and deduction of the distance between the circles.
6. Selection of white areas inside the circles and black areas on the circles.
7. Computation of the attenuation coefficients.

A summary of the different steps is illustrated in Figure 6.

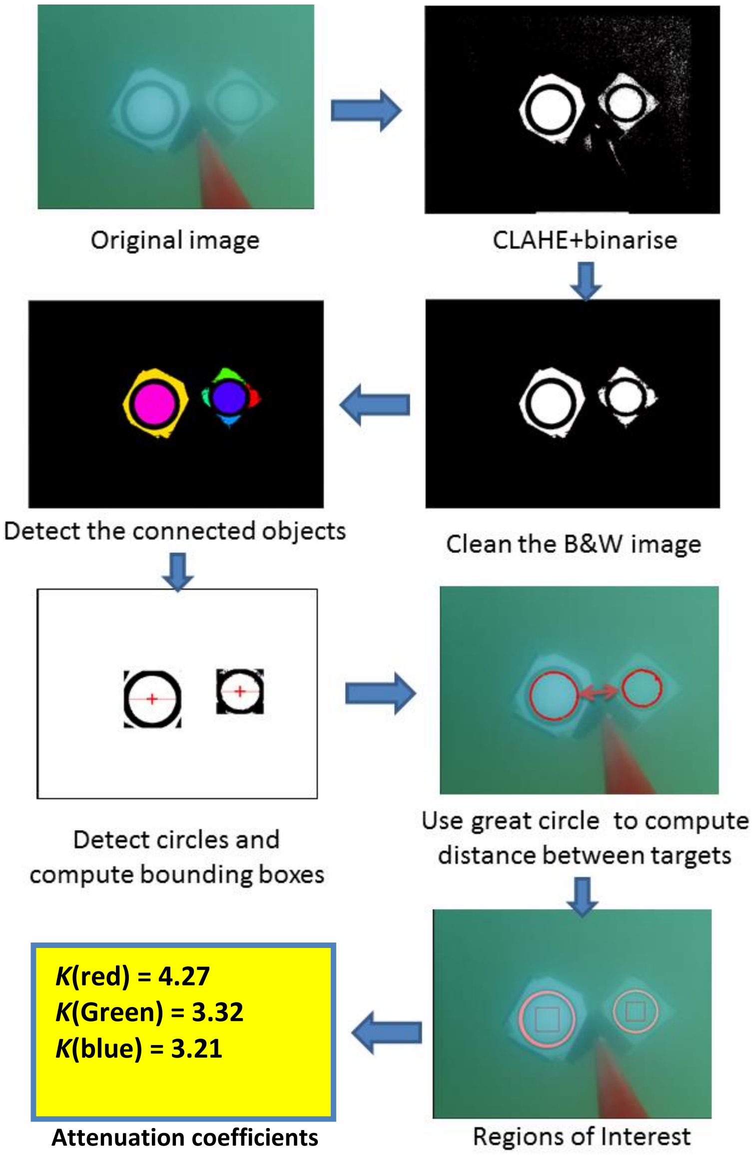

Figure 6. Illustration of the different steps of the algorithm used to compute the attenuation coefficients from underwater images

The results have been demonstrated in field campaigns in Spain. Some examples of pictures taken by volunteers are shown in Figure 7. Various publications and presentations in conferences have been produced out of these results.

Results also include two **fluorescence sensory systems for smart phone environments**: one based on affordable external sensors integrated via smart phone applications, and one directly exploiting existing mobile sensor systems. These novel sensory systems are explained below:

a) A matrix fluorometer which combines measurements of different substances in water by means of different excitation-emission combinations. These combinations allow the user to adjust the instrument to distinguish algal groups, or sources of CDOM.
b) Two different systems for direct measurements of fluorescence. One system contains only default elements of a smart phone for excitation and emission of light, and is hence restricted to record Chl *a*; the second system integrates external LEDs and thereby allows measurements of fCDOM and potentially other substances.

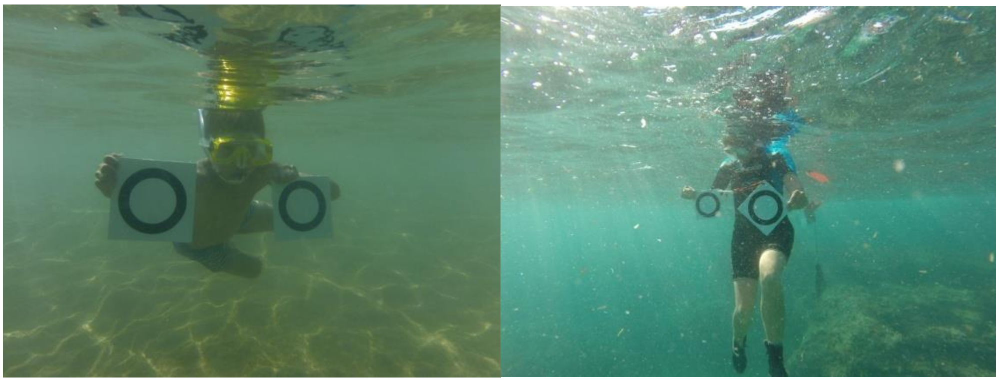

Figure 7. Volunteers using the TrandiCam

Results also include several ***quality control*** **(QC) methodologies and recommendations**, which are needed to minimize the impact of ambient light conditions on the interpretation of the measurements of colour, fluorescence and transparency. Active QC (that gives directions at the time of the measurement) and passive QC (that applies rules in the processing of data) have been used. One of the most important problems for the kind of measurements carried out in Citclops is that a fraction of the incoming sunlight is reflected at the surface of the water and contributes to the signal when an observation of the water colour is made. Another key problem is that, in shallow water, the sun and sky are refracted at the surface and rapidly changing patterns of high intensity emerge (see Figure 8). This affects the colour and the transparency measurements.

The main recommendations for the FU scales, which were taken into account and included in the apps developed, are the following ones:

- Study of the difference of results depending on the smartphone camera characteristics (The model of the camera needs to be considered.)
- Systematic use of the Secchi disk
- Pictures taken in the shade
- Explanation of the best position of the smartphone with respect to the nadir and the azimuth angle
- Asking volunteers if the sea bottom is seen
- Checking if it rains
- Collection of information on the wind conditions

The main recommendations for KdUINO (sensor buoy), which were taken into account and included in the app developed, are the following ones:

- The first (top) sensor should be at least 30 cm below the water surface.
- The exact depth of each sensor has to be known.
- Data have to be deleted if sensors are saturated at a particular moment.
- r^2 of the linear regression should be higher than a predefined threshold.
- Specific calibration has to be ensured for each buoy.
- Care should be taken to reduce the systematic shading of the sensors during deployment.

The main recommendations for the TrandiCam (underwater pictures system), which should be systematically transmitted to the volunteers in an instruction manual, are the following ones:

- Always take pictures with the sun on the back of the plate holder.
- Take more than one picture at the same location and time.
- Do not overlap the two plates.

- One plate should not shadow the other one.

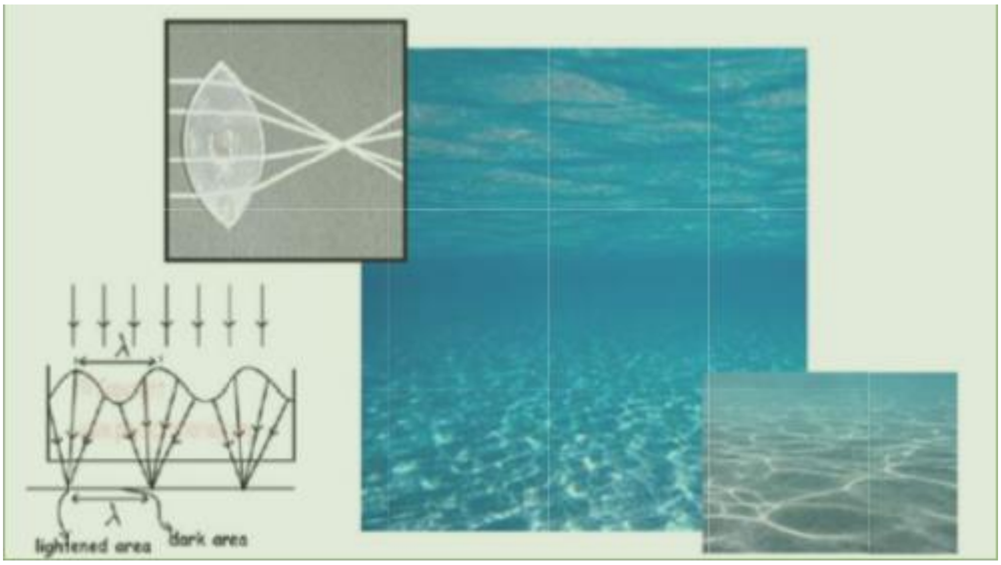

Figure 8. Light refraction at the surface and its effects on vertical light attenuation

The main recommendations about fluorescence measurements are the following ones:

- Duplicate/triplicate measurements are recommended. A mean will be the output value.
- Check if significant time difference between measurement and sampling occurs.
- Check the sampling light conditions (sunny, cloudy) and temperature, if possible.
- Check dark measurements of the cuvette before and after excitations with LED.
- Check availability of a blank measurement for calibration.
- Check disturbing influences of scattering by particles in the water.
- Determine internal camera settings.

1.3.2. End user applications

Novel applications have been developed to allow citizens to play a central role in Citclops. By enabling their personal phones as smart information gateways responsible for collecting, processing and forwarding sensor data, citizens become the active agents for environmental monitoring. To do so, citizens have been provided with a set of user tools favouring their engagement with the system by means of a simple, powerful and friendly interaction. This main results are:

- the implementation of a research methodology for end-user involvement in the development and validation process;
- the deployment of a device interoperability framework supporting a simplified and user-friendly integration of sensor devices;
- the implementation of a mobile processing module for integrating, optimizing and transferring sensor data by properly managing the available computational resources;
- the development of a rich and personalized user interaction layer for data sharing and information delivery over mobile devices and the Internet.

One specific result is the **integration of external sensor devices**, which consists of the integration environment enabling a seamless communication between the citizen’s mobile phone and the surrounding sensor devices. Because of the citizens’ role, providing their smart phones with capabilities for autonomous device discovery, routing and communications was crucial. To handle the heterogeneity of the sensing scenarios of the system, a decoupled communication layer allowing multi-protocol implementations has been defined. Additionally, user-friendliness of the overall device integration process has been kept as a key objective.

Another result is a **mobile user-interaction layer**. Raising citizen engagement is a key success factor for a social-sensing system such as Citclops. That is why providing users with a powerful, personalised and highly usable tool was crucial. And the mobile user-interaction layer is the citizen’s entry point to the system. This layer supports the two main functional goals for the Citclops citizen tools: to be able to easily capture and share the environmental data, and to deliver the processed information on environmental conditions. Usability for mobile devices, complex data visualisation, and personalisation of interfaces have been jointly addressed. The user interaction layer has been implemented in the different applications supporting the usage scenarios depicted for the system.

The main challenge consisted in creating an easy, personalised, useful and fully accessible user interaction layer capable of supporting citizen engagement with the system. The user insights collected through successive iterations have been analyzed together with the non-functional requirements related to the device ecosystem, and realised through the user-centric development methodology adopted.

At the end of the project, thanks to the development of the mobile user-interaction layer, **three independent applications (apps)** are available to the public:

- Colour:
  - *Citclops - Citizen water colour monitoring* app (published in App Store and Google Play), that allows the colour of the water to be measured (superseded by the EyeOnWater - Colour app)
  - ***EyeOnWater - Colour* app** (published in App Store and Google Play): a new version of the Citclops - Citizen water colour monitoring app
- Fluorescence:
  - *AppLED*: app developed to be used in fluorescence-related lab tests (superseded by the FluorescenceApp)
  - ***FluorescenceApp***: a new version of the AppLED
- Transparency:
  - ***KdUINO Remote Control* app**: an app to analyse water transparency

Another result is the **user involvement in development and evaluation**. Since the user acceptance of the system is a major success factor for social-driven projects such as Citclops, a specific and well-focused effort for defining and implementing a user-driven design was required. Citclops processed user requirements and provided the resulting specifications as input for the development tasks. The background was provided by existing and novel methods for assessing acceptance, rate of uptake, user experience and usability.

1.3.3. Citizens' education and participation in environmental stewardship

A major result of the project is to have **successfully approached the citizens and improved their understanding of aquatic environmental observations and monitoring**, with the aim of enhancing community decision-making and cooperative planning. Different channels were used to foster the engagement of citizens and provide them and decision-makers access to scientific knowledge and competence:

- Blue Info-days and Open House events
- Dedicated training events
- Environmental visitor centres
- Internet and social media

Relevant stakeholders in citizen science (citizens, researchers, and decision makers) were brought together in many of these events, which supported public involvement and participation in decision making processes. Within the project course, the measurement of three bio-optical descriptors of water were was enabled in affordable and easy-to-use tools. Citizens were involved at an early stage, to align the project's development with their interests. The full process, from first concept to prototype of new and innovative techniques, however, requires long time-spans (from a citizen's perspective). Hence, the timing in sharing material and prototypes with the public was carefully selected. Direct and indirect feedback mechanisms were implemented:

- Personal communication during events
- Website questionnaires
- Social media such as Twitter and Google+
- Feedback field within the Citclops - Citizen water colour monitoring app
- Feedback via the use of apps and data uploads

Strategies and plans to increase environmental awareness and public involvement were promoted by dedicated training events and social media activities for all stakeholder groups of citizens. Next-generation citizens were also engaged in environmental stewardship by dedicated actions for school classes and the inclusion of specific groups, such as the Junior Rangers. The Citclops tools and methodology to involve citizens in environmental monitoring are, at the end of the project, ready for adoption by a wider public. This may include ferry passengers on selected ferry lines, or citizens interested in answering specific environment-related questions in real case scenarios outside of the scope of Citclops.

A specific result is represented by the **Citclops Blue Info-days**. The concept of the Citclops Blue Info-days was developed to foster the engagement of citizens in environmental governance and citizen science, and to provide the possibility for a two-way feedback between citizens and developers. These events are structured in a theoretical part and several hands-on experiences (see Figure 9). Discussion and feedback between participants and the Citclops crew were promoted during the Blue Info-days. The events have been accompanied by the production of educational material and traditional-media and social-media coverage, in particular by real-time Twitter updates.

Blue Info-days were well visited and contacts with future user groups could be established, e.g., with kayak groups in Germany and Spain. Furthermore, a direct feedback loop on Citclops tools was possible between researchers and citizens, which aided the alignment of tools with citizens interests and behaviours. The events included participants from all stakeholder groups: citizens, researchers and decision makers, and hence fostered environmental stewardship and governance issues. Presentations from monitoring and management entities were held and represented a good starting point for cooperation with different user groups.

Figure 9. Citclops Blue Info-days held in Wilhelmshaven, Germany and Wexford, Ireland. Both events were structured in theoretical parts, a) in Wilhelmshaven and b) in Wexford, and in practical units, c) in Wilhelmshaven and d) in Wexford. Source: a, c) M. Schneider; b) P. Thijsse, d) A. Friedrichs.

A large number of activities were offered to citizens during the project execution-time (see Figure 10). Training was performed by mentor scientists from the Citclops group and supported by local environmental scientist from the pilot case areas. All age classes were addressed in these events. Besides age-mixed groups, dedicated groups of next-generation citizens (e.g., Junior Rangers) (see Figure 11) and seniors were engaged.

Figure 10. Dedicated training events were used to foster the engagement of citizens and provide them and decision-makers access to scientific knowledge and competence: a) application of Citclops techniques, at a kayaker´s training in Llançà, Spain; b) inclusion of senior citizens during a trip with an ICBM research vessel in Jade Bay, Wilhelmshaven, Germany; c) kayaker´s training in the North Sea; d) scientific oral and poster contributions at the Ocean Optics conference in Portland, 2014; e) event for the general public during the German Union Day in Hannover, Germany; f) the Ocean Sampling Day, with combined biodiversity sampling and Citclops bio-optical measurements.

Figure 11. Next generation citizens were engaged in environmental stewardship during the Blue Info-days in a) Germany; and b, c) Ireland; and during other dedicated training events, such as d) the Science festival in Barcelona; e) a NIOZ event in Texel; and f) a TrandiCam event in the Ebro Delta. Image sources: a) M. Roebbelen, b) Anna Friedrichs, c) Julia Busch, d) Carine Simon, e) Marcel Wernand, f) Plàncton.

A strong response (also with respect to uploads of water-colour observations) was received by coupling Citclops to larger events, such as the Ocean Sampling Day or the Barcelona World Race organized by the Fundació Navegació Oceànica Barcelona (FNOB) [http://www.fnob.org/].

Another result was the **citizen involvement in decision making and coordination with local decision makers**. Strategies and plans to increase the environmental awareness and public involvement were evaluated during participatory events with all stakeholder groups of citizen science: citizens, researchers and decision makers. These included the Blue Info-days in Wilhelmshaven, Germany, and in Wexford, Ireland, but also events such as workshops with scientists and civil servants working for national and local water authorities

(EPA in Ireland; Rijkswaterstaat, Ministry of Infrastructure & Environment in The Netherlands), Coastwatch regional coordinators and secondary school students in the Carlingford Adventure Centre, Ireland. Recommendations and observations for strategies and plans to increase the environmental awareness and public involvement have been compiled and include:

- A clear explanation of the usefulness, methodology and interpretation of the data should be provided so citizens build up a firm ocean literacy foundation.
- Very few citizens go out to report regularly for the sake of reporting and aiding a greater scientific goal, though some do. So scientists' expectations have to be tuned into how and when citizens will use the technology to produce data. After learning about ocean colour and transparency and the recording and reporting techniques, most citizens are ready to use them once, and thereafter like first aid, i.e. when needed. The need arises either because one wants to boast about amazing water transparency, or there is a mass event on (like Ocean Sampling Day); most likely, the use is triggered by unusual water conditions noticed by the citizen who has been made conscious of these. This purposeful use of citizen-science apps introduces a welcome sampling bias towards events: algal blooms, pollution incidents or dredging, for instance. Researchers can pick this up from the sudden increase in reporting traffic in an area.
- Project planners should ensure that they know the citizens' level of baseline knowledge and understanding on a subject before finalising project plans: some plants, common seashells and charismatic megafauna, as well as threats like sewage pollution and litter, have been covered well for years and are familiar. The lack of knowledge, coupled with misconceptions about water colour and transparency, was a real hindrance in this project and took a lot of extra work to overcome, only achieved towards the end of the project.
- There are many competing citizen science projects on offer now. Citizens' choices on if/where to participate and engage in the future also depends on the experience in any given previous project. So there is a serious responsibility of projects to ensure citizens have a positive experience, judged by environmental impact, or as a skill learnt, or as a tool which can be applied when needed. And the strength and limits of these tools need to be understood.
- Citizens are drawn in by curiosity and might stay for many laudable reasons, but fun is one often mentioned.
- Sustained engagement is facilitated by meaningful response to the citizen’s effort. In the case of app use, meaningful response is a motivating, useful feedback via the app.

1.3.4. Interoperability

The following results related to **interoperability** have been achieved:

(1) a data management system for archiving all collected Citclops data, including metadata, interoperable with the SeaDataNet-EMODnet infrastructure to support two-way exchange;
(2) tools for validating the gathered data, also using long-term environmental datasets as available through SeaDataNet and EMODnet;
(3) a service for discovery, access, and visualisation of the Citclops data.

Incoming Citclops data are managed in a standardised way thanks to the workflow visualised in Figure 12. On the left, Citclops data (optical properties of water: colour, transparency Kd, fluorescence) are being collected by sensors; then they stored in a database together with metadata. The right side of the diagram shows how data are published to users, either directly via the Citclops portal, or indirectly overarching portals like EMODnet and GEOSS.

Another result is the definition of formats for **metadata description and storage of datasets**. Within the Citclops project a metadata format has been created based on the existing Common Data Index (CDI) metadata standard by SeaDataNet and EMODnet. Because this metadata standard, and, in particular, the controlled vocabularies in it, were not fully covering citizen-observation data using apps, Citclops has then influenced the standardising bodies of SeaDataNet, having them add several new vocabulary terms (e.g. new device types and new parameters codes) and definitions.

Another result is the **definition of a validation scheme for citizen-science data**, which has been implemented for water colour data and has two components:

- *Direct*: Incoming data are checked using a QC algorithm automatically calculating the FU value. This algorithm makes use of the RGB values of the image in combination with the metadata of the observation.

- *Indirect*: Via the EyeOnWater website [www.eyeonwater.org] users can flag measurements of other users (see Figure 13). A flagged observation is emailed to an expert who can remove the observation from the system in one click. Flagged images are not discarded, but receive a flag in the database.

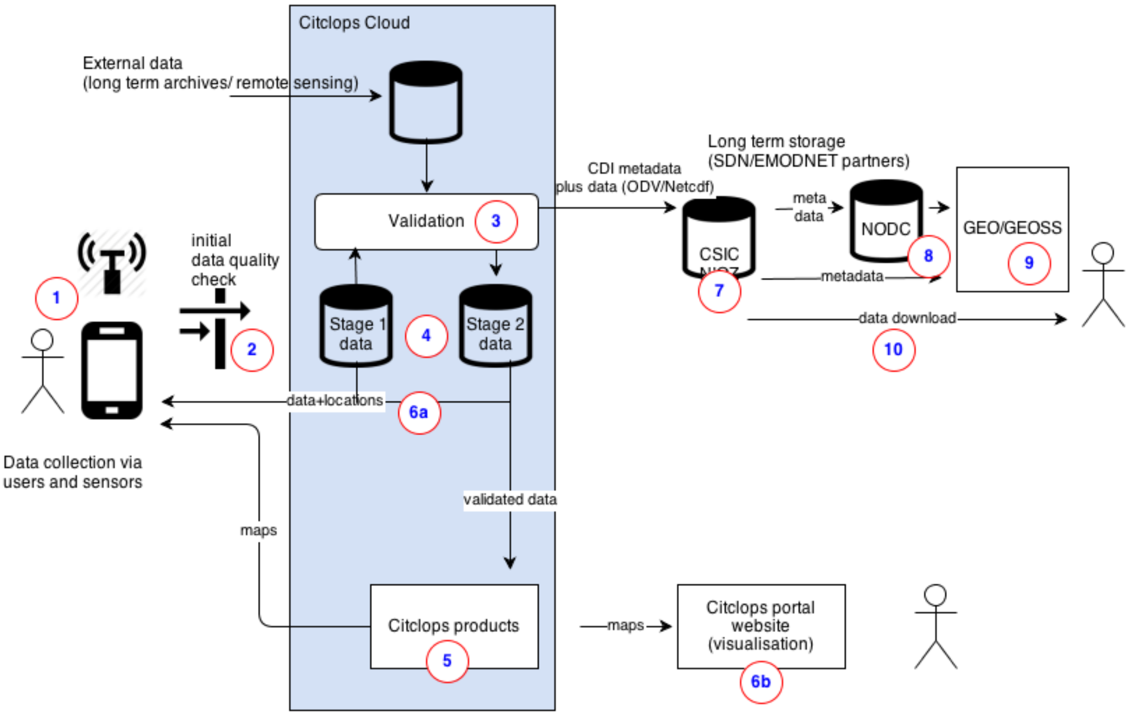

Figure 12. Data flow of Citclops data to users and external systems

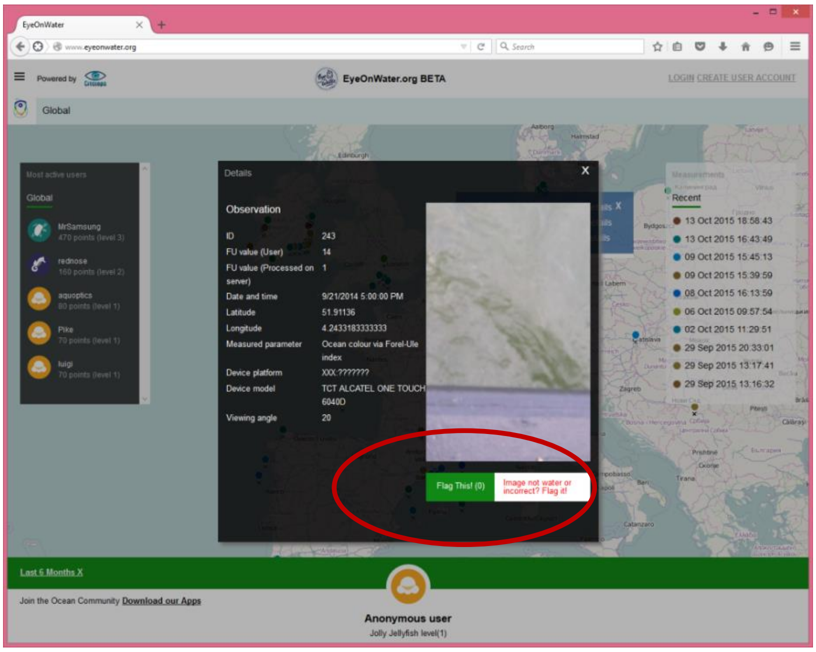

Figure 13. Flagging option for the users

Other results include **a data management system, machine-to-machine interfaces, a validation workflow, and mobile-platform user interfaces**:

- *Validation / quality control*: An algorithm has been implemented to process FU values on incoming data. It is implemented as executable MATLAB encoding on EyeOnWater app data.
- *WMS/Getfeature info services*: OGC compliant WMS (plus GetFeatureInfo) and WFS services have been developed to make use of Citclops data in map applications. The WMS service for Citclops data as well as the historic FU dataset has been **published to the GEO/GEOSS portal**:

[http://geossregistries.info/geosspub/resource_details_ns.jsp?compId=urn:geoss:csr:resource:urn:uuid:5dc54869-d8a1-0ee8-d7e6-993a305a310c] (see Figure 14).

- *The EyeOnWater website* [www.eyeonwater.org] (see Figure 15): It was developed to display the data collected via the EyeOnWater app (plus via previous apps) and to give the citizen a personal experience. The aim has been to make EyeOnWater a concept that goes beyond Citclops and focuses on citizens. This website will be updated and hopefully expanded with other parameters in the coming years.
- *Export of metadata and data to CDI metadata format and ODV data-file*: The metadata format of Citclops/EyeOnWater observations has been developed compliant to international metadata standards from SeaDataNet. This enables easy export of metadata to CDI metadata files and ODV data-files to allow an easy transfer of data from EyeOnWater to data centres connected to SeaDataNet/EMODnet. The export of data collected has been tested using MIKADO software to generate CDI files.

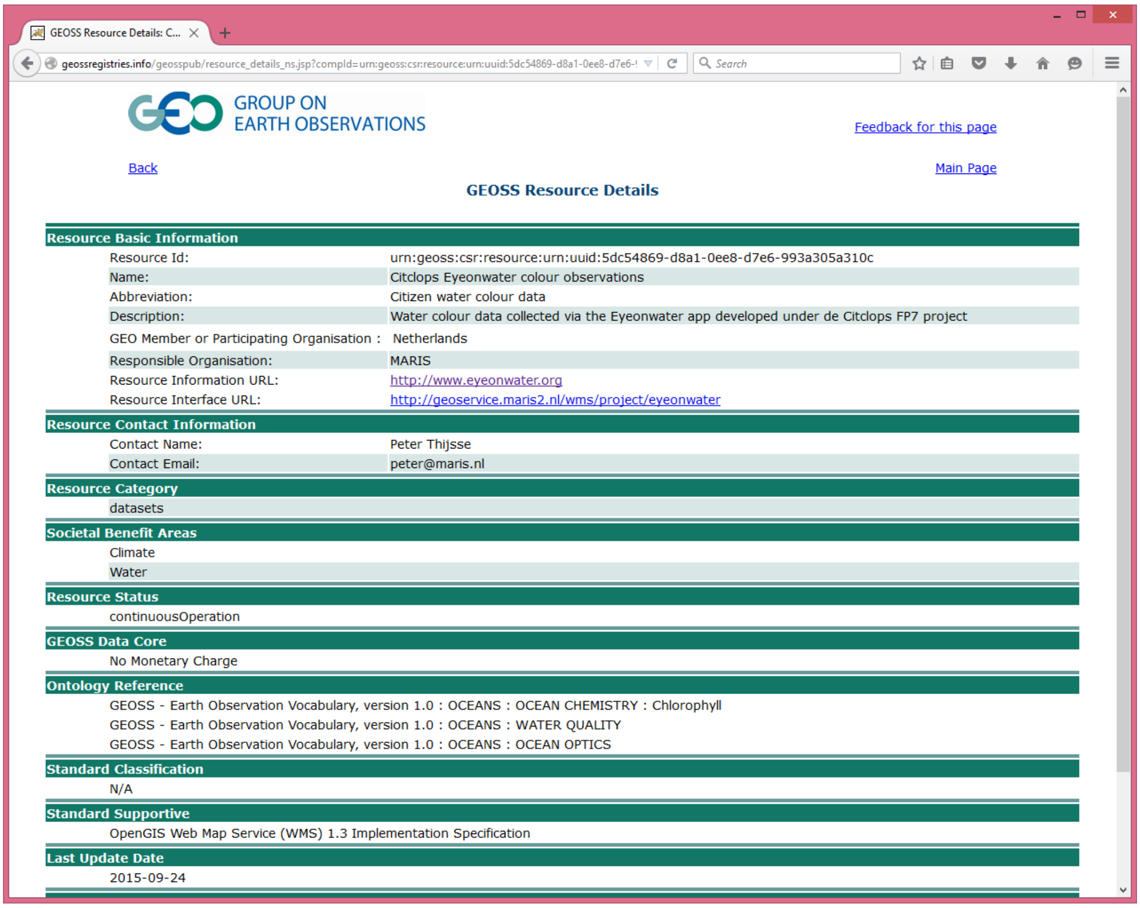

Figure 14: Snapshot of Citclops's GEOSS registration

Other results include **sensor--to--mobile-device interfaces based on open standards**. Demonstrations with KdUINO showed that *sensor observation service* (SOS) standards can be used to link sensors to mobile devices/platforms, specifically for remote sensor identification and retrieval of observations.

1.3.5. Artificial intelligence

Citclops dealt with *knowledge-based systems* (KBSs) whose abilities derive, at least in part, by reasoning over an explicit knowledge base. By a *knowledge base*, Citclops's partners mean a collection of data structures that have two properties: they can be interpreted as sentences that constitute at least part of the knowledge that the system exhibits; and second, they influence the behaviour of the system in an active way (i.e., they are not just comments in a program). Citclops focused on in particular a certain component of KBSs called the *knowledge representation system*. Its job is to manage the knowledge base for the overall system. So it is the one to select the data structures to use to represent the knowledge and to apply reasoning methods that are appropriate for dealing with these data structures. In other words, it is the knowledge representation system that has to worry about applying all the domain knowledge.

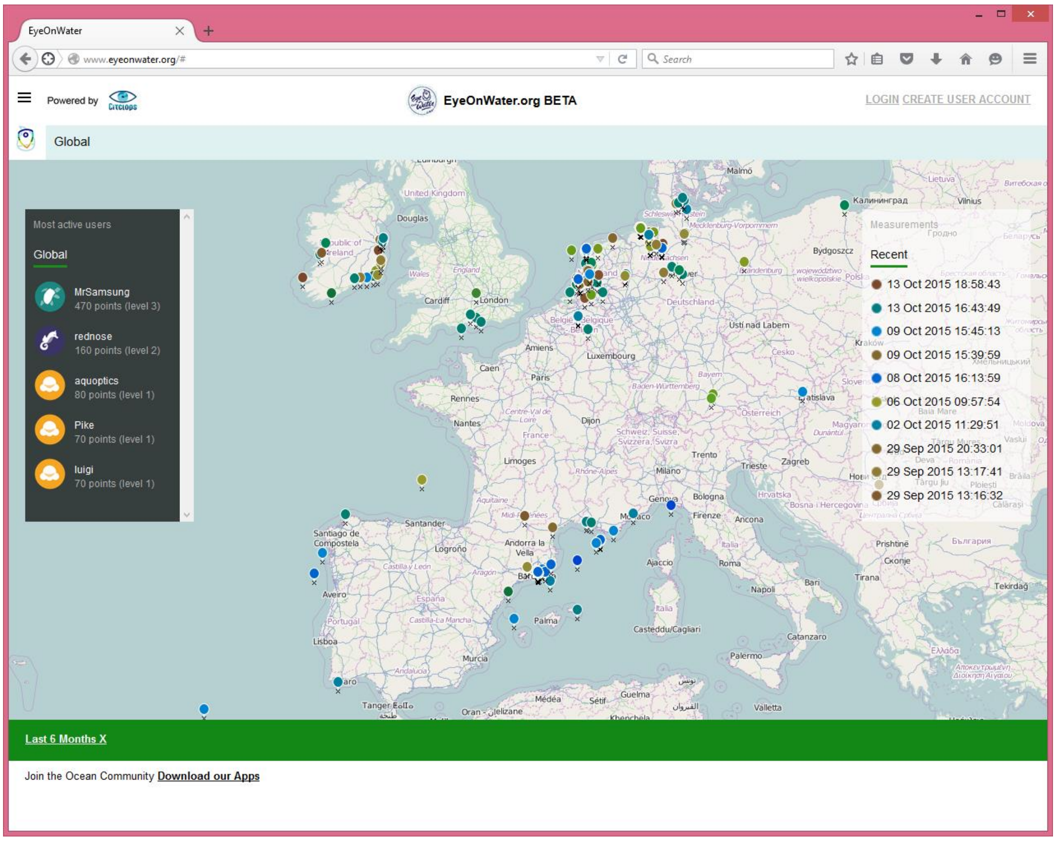

Figure 15: Screenshot of [www.eyeonwater.org] showing all water colour data collected

The knowledge representation system and other artificial-intelligence systems have been used in developing software to:

- interface different technologies to create Web-based end-user applications;
- integrate different components;
- implement feedback from end-users as delivered via citizen-science interfaces;
- interpret the data collected; and
- deliver new information to the citizens.

The proper exploitation of the information generated from the sensed data lies heavily on the development of high-quality end-user applications. In addition to the applications specifically targeted to citizens described earlier, an application aimed to the exploitation of the aggregated data by citizens, decision makers and researchers has also been developed. From an initial conceptualisation, this application evolved into a rich Web-based data exploitation environment providing citizens, decision makers and researchers with an integrated tool for graphical analytics and pattern detection on environmental data. State-of-the-art research on visualisation techniques for complex and disparate data has been analyzed to provide the technical basis for this. Composition of data sources has also been implemented.

One major result in this respect is the interpretation of data and delivery of information carried out via a *decision support system* named '**Citclops Data Explorer**', available from the main project portal at [http://www.citclops.eu/participate/citclops-data-explorer] (see Figure 16).

The knowledge-based system behind the Citclops Data Explorer includes rules which relate sensor data streams, archived data sets and ecological status. The local context conditions taken into account via the integration of available results of regular monitoring by governmental organisations. Different platforms have been necessary in order to develop the components of the Citclops Data Explorer (e.g., water-quality sensor technology, mobile and Web applications). Of particular importance to the users has been the integration among the end-user apps for data collection, the user interface and the data server used as a repository. This integration of all components into one single system can be accessed by the users via the project portal [http://www.citclops.eu] (see Figure 17).

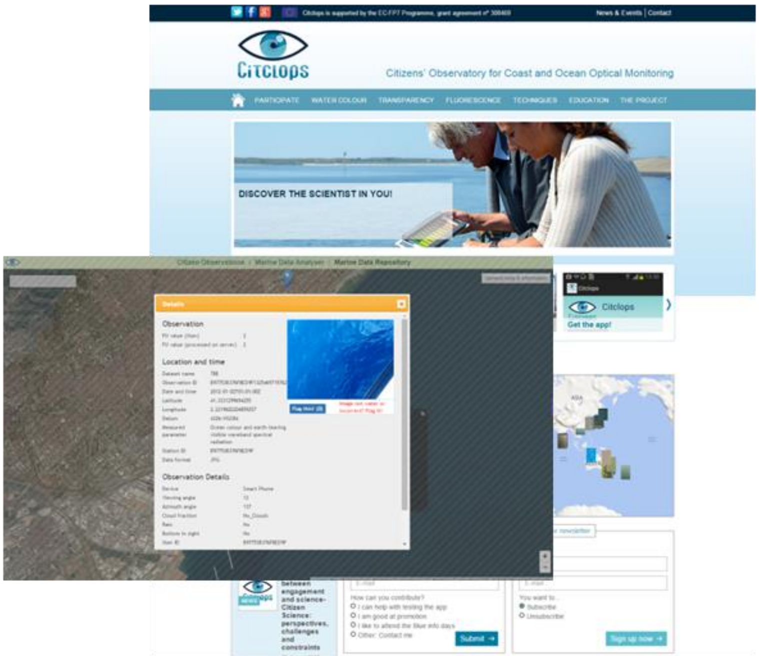

Figure 16. Citclops's portal interface

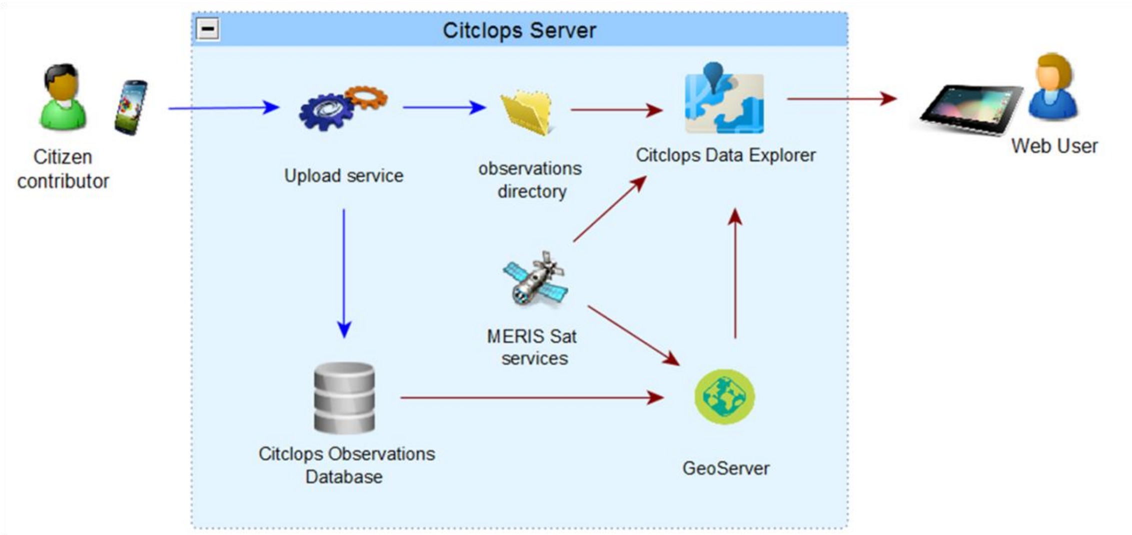

Figure 17. Citclops's high-level architecture

Related results include **data *quality-control* (QC) methods**, which have been deployed for data interpretation. The QC consists of a protocol with knowledge rules that can analyse the status of an observation. Additionally, information is provided to the observer citizen via the app interface with directions to improve the measurements.

Another result was the **specification of suitable development platforms for citizen-science projects**. A careful choice of the development platforms has reduced integration problems of different technologies. A comparison of real-time systems for data processing resulted in the definition of the development platforms and technologies used in Citclops's back-end (see Figure 18) and front-end (see Figure 19).

Another result was the **specification of suitable user interfaces for citizen-science projects**. The Citclops Data Explorer presents three interfaces based on the content presented:

- Citizen Observations [http://webmap.citclops.eu/citizen-observations] (see Figure 20)
- Marine Data Analyser [http://webmap.citclops.eu/marine-data-analyser] (see Figure 21)
- Marine Data Repository [http://webmap.citclops.eu/marine-data-repository]

Figure 18. Citclops's back-end technologies

All the different data-collection technologies have been integrated into one system and controlled via these three interfaces.

Figure 19. Citclops's front-end technologies

Figure 20. 'Citizen Observations' interface

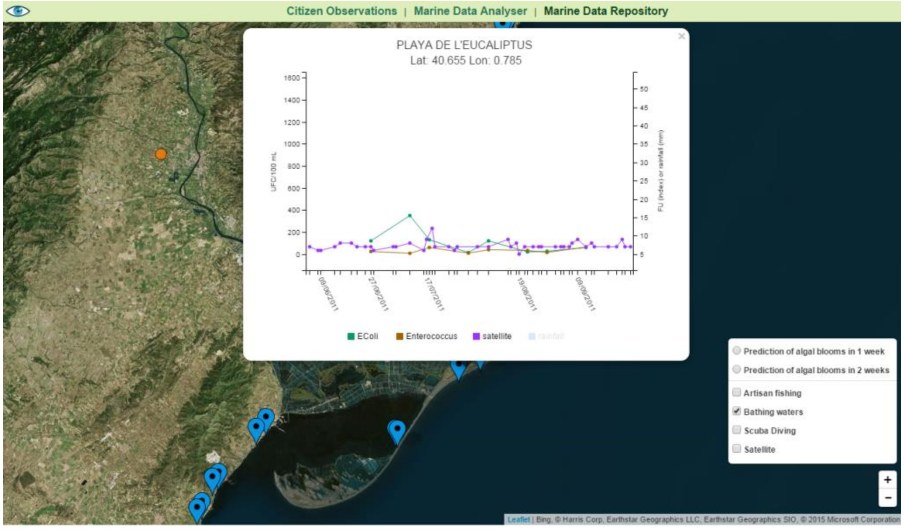

Figure 21. 'Marine Data Analyser' interface

The Citclops Data Explorer is a knowledge-based system for data interpretation and prediction, and information delivery. The reasoning system is based on inductive learning and relates new-sensor data streams, ecological status and archived data sets. To this aim, EC directives that apply to specific types of geography and the local ecological status have been considered. The local context conditions have also been studied via the reports and available results of regular monitoring by governmental organisations. The basic methodology that couples the measurements to the ecological phenomena (like coupling of colour to bloom phenomena) has been described in computational terms.

With respect to information delivery, any citizen can navigate through all the observations of seawater (see Figure 22) taken by user of the Citclops smartphone apps or uploaded manually using a dedicated web interface [http://www.citclops.eu/participate/upload-your-image].

Figure 22. Detail of the 'Citizen Observations' interface

1.3.6. Dissemination, standardisation and sustainability

With respect to dissemination and standardisation, the following results have been achieved:

(1) promotional and dissemination activities to potential users and providers;
(2) integration of Citclops metadata into existing standards;
(3) establishment of a sustained (long-term) operation of the Citclops services.

Part of these results consist in the **promotion and dissemination of Citclops outputs** to the scientific community (through publications and presentations) as well as to the general public and stakeholders.

Specific results are as follows:

- Promotion of citizen science via the Citclops website, publishing news, events, documentation and via user interfaces presenting the collected data and information.
- Presence of Citclops in social media, e.g. Facebook, Twitter and Google+.
- Adoption of Citclops metadata by standardisation bodies (SeaDataNet, OGC) and adaptation of existing standards to Citclops (and other citizen observatories)'s needs. Adaptation has been achieved, e.g., by the expansion of SeaDataNet vocabularies of controlled term to suit marine citizen observatory data. Also, discussions have taken place with OGC and other citizen observatory projects on how to implement SWE for citizen data.
- Development of the Citclops website (see Figure 23).
- Development of the EyeOnWater website (see Figure 24).
- Presence in several meetings, conferences, and events, e.g. the Barcelona World Race [http://www.citclops-barcelonaworldrace.org/].
- Organisation of Blue Info-days and, within those, of "open house events" (see Figure 25) to create a "living lab" experience where citizens get into direct contact with scientists and developers.

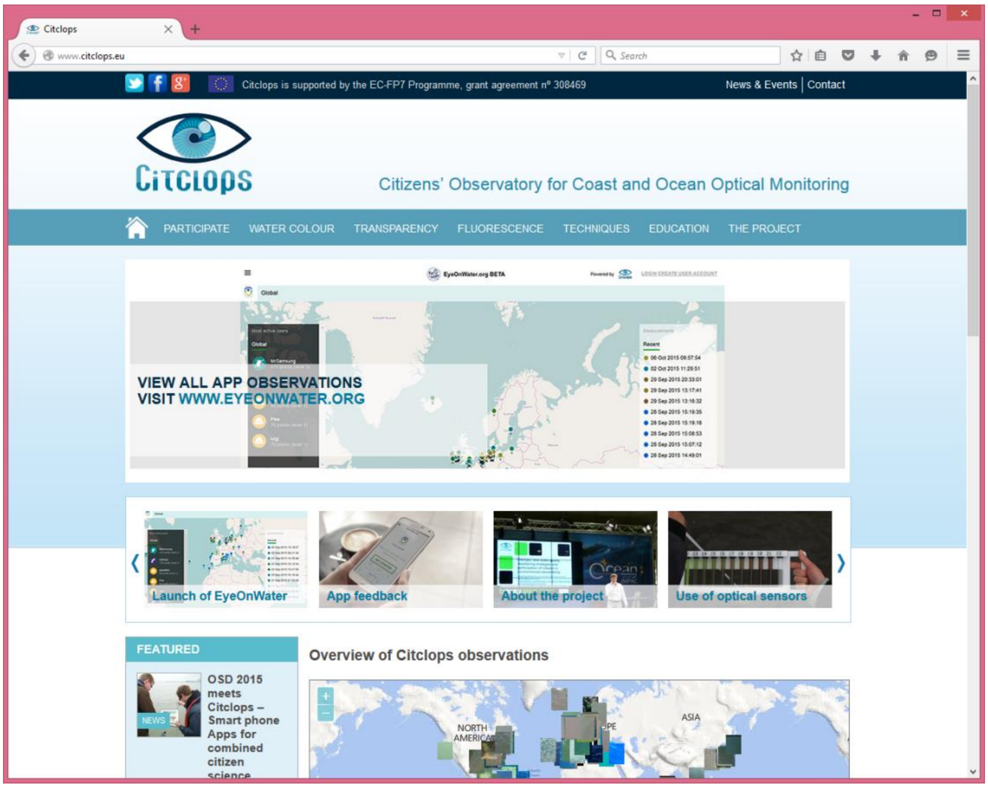

Figure 23. Citclops website

- Active presence on social media, e.g. Facebook, Twitter, Google+ and LinkedIn:
  - https://plus.google.com/102181745587261283861
  - https://plus.google.com/communities/113633358709457603658
  - https://www.facebook.com/groups/254888394582316/
  - https://twitter.com/Citclops
  - http://www.linkedin.com/groups/Citclops-4788061

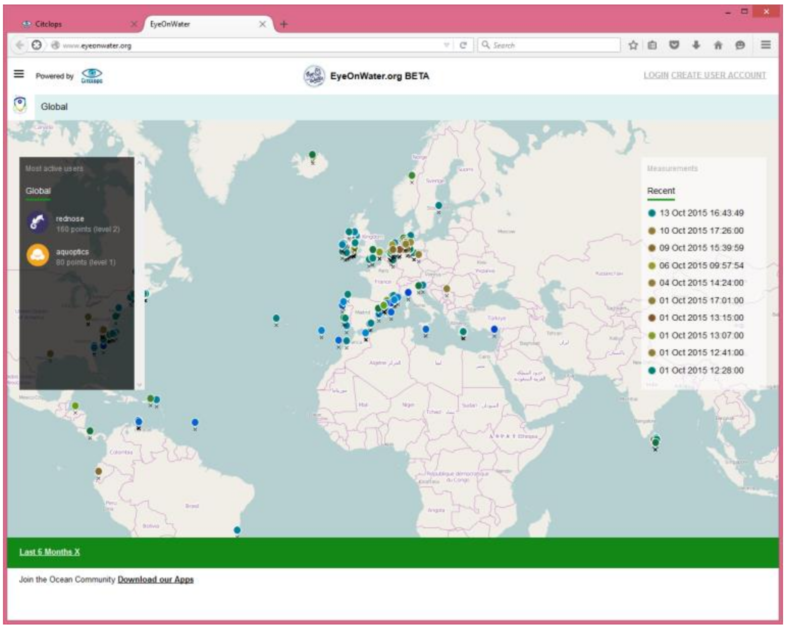

Figure 24. EyeOnWater website

Figure 25. Citclops's open house events

Results include the following publications in the period 2013-2015:

- In preparation – **Blauw**, Anouk, Meinte Blaas, Henk van den Boogaard, Naomi Greenwood, Wilhelm Petersen, Marcel Wernand, Hans van der Woerd, Remi Laane; “Reliable detection of changes in marine phytoplankton concentrations: the balance between number and quality of data.” (in prep. for Journal: Global Change Biology)
- In preparation - **Friedrichs** Anna; Julia A. Busch; Christopher John; Hans J. van der Woerd; and Oliver Zielinski “Measuring chlorophyll a fluorescence in water by means of smart phones”, (in prep. for Limnology Oceanography: Methods).
- In press - **Busch**, J. A., Price, I., Jeansou, E., Zielinski, O., van der Woerd, H.J. "Citizens and satellites: assessment of phytoplankton dynamics in a NW Mediterranean aquaculture zone", International Journal of Applied Earth Observation and Geoinformation.
- 2015 - **Bardají Benach**, R., Carine Simon, Albert Miquel Sánchez Delgado, Jaume Piera Fernández “Advances with the KdUINO, the low-cost buoy to measure the attenuation coefficient”, 4th EOS Topical Meeting on Blue Photonics - Optics in the Sea (Blue Photonics 4).
- 2015 - **Bardají Benach**, R., Carine Simon, Albert-Miquel Sanchez Delgado, Marcel Wernand, Jaume Piera Fernández “Advances with the KdUINO, the low-cost buoy to measure Kd”, Blue Photonics - Optics in the Sea.
- 2015 - **Bardají Benach**, R., Carine Simon, Jaime Piera Fernandez. “The great potential of KdUINO, a citizen science instrument”, ASLO, Aquatic Sciences Meeting.
- 2015 – **Busch**, J. A., “Potential of affordable bio-optical sensors in marine citizens’ observatories”, 4th EOS Topical Meeting on Blue Photonics - Optics in the Sea (Blue Photonics 4).
- 2015 – **Busch**, J. A., Emilien Bernard, Luigi Ceccaroni, Eric Jeansou, Jaume Piera, Ivan Price, Stefani Novoa, Peter Thijsse, Hans van der Woerd, Marcel Wernand, Oliver Zielinski. Citizen Science

approach to characterize phytoplankton dynamics in the Ebro Delta, NW Mediterranean, ASLO, Aquatic Sciences Meeting

- 2015 - **Ceccaroni**, L., Blaas, M., Wernand, M. R., Velickovski, F., Blauw, A. and Subirats, L. *A decision support system for water quality in the Wadden Sea*. Proceedings of the 47th International Liege Colloquium on Ocean Dynamics. Liège, Belgium. May 2015.
- 2015 - **Ceccaroni**, L., Velickovski, F., Blaas, M., Wernand, M. R., Blauw, A. and Subirats, L. *Citclops Data Explorer: exploring water quality in the Wadden Sea*. Proceedings of the Environmental information infrastructures and platforms (ENVIP'2015) workshop. Barcelona, Spain. October 2015.
- 2015 - **Ceccaroni**, L., Velickovski, F., Steblin, A. and Subirats, L. *Citclops: data interpretation and knowledge-based systems integration*. Proceedings of the Environmental information infrastructures and platforms (ENVIP'2015) workshop. Barcelona, Spain. October 2015.
- 2015 – **Friedrichs** Anna, Julia A. Busch, C. John, H.J. van der Woerd, O. Zielinski, “The way from a smart phone to an affordable fluorescence sensor for phytoplankton retrieval”, 4th EOS Topical Meeting on Blue Photonics - Optics in the Sea (Blue Photonics 4).
- 2015 – **Friedrichs** Anna, Julia A. Busch1, Hans J. van der Woerd ,Christopher. John, and Oliver Zielinski, “Measuring fluorescence by means of smart phones with the new Citclops Application”, ASLO, Aquatic Sciences Meeting
- 2015 – **Kopf**, A.,[..], Busch, J. A., et al., The ocean sampling day consortium. Giga Science 4:27
- 2015 - **Novoa**, S., Wernand, M. and van der Woerd, H. J. "WACODI: A generic algorithm to derive the intrinsic color of natural waters from digital images", Limnology and Oceanography: Methods. DOI: 10.1002/lom3.10059.
- 2015 - **Simon**, C., Raul Bardají Benach, Jaume Piera Fernández “Underwater Imaging and Citizen Science to estimate Water Transparency”, 4th EOS Topical Meeting on Blue Photonics - Optics in the Sea (Blue Photonics 4).
- 2015 - **Simon**, C., Raul Bardají Benach; Jaume Piera Fernández “Underwater Imaging and Citizen Science to estimate Water Transparency”, Blue Photonics - Optics in the Sea.
- 2015 - **Simon**, C., Raul Bardají Benach; Jaime Piera Fernandez “Estimating water transparency from citizen science underwater pictures”, ASLO, Aquatic Sciences Meeting.
- 2015 - **Woerd** H. J., Wernand M. R. "True Colour Classification of Natural Waters with Medium-Spectral Resolution Satellites: SeaWiFS, MODIS, MERIS and OLCI", *Sensors*. 2015; 15(10):25663-25680.
- 2014 - **Bardají Benach**, R., Carine Simon; Eloy Zafra Santos; Jaime Piera Fernandez. “A spatio-temporal analysis with KdUINO data, a DIY citizen science instrument”, Ocean Optics Conference XXII.
- 2014 - **Bardají Benach**, R., Eloy Zafra Santos, Carine Simon, Jaime Piera Fernandez. “Comparing water transparency measurements obtained with low-cost citizen science instruments and high-quality oceanographic instruments”, Oceans'14 MTS/IEEE Conference.
- 2014 – **Busch**, J. A., Strategies for engaging citizen collectives. Open conference on Citizens’ Observatories: Empowering European Society, Management Centre Europe, Brussels, Belgium, December 4, 2014.
- 2014 – **Busch**, J. A., Emilien Berard, Eric Jeansou, Ivan Price, Hans van der Woerd, Oliver Zielinski “Changes of water colour in the aquaculture zone of the Ebro Delta, NW Mediterranean-pilot site for citizens observatory”, Ocean Optics Conference XXII.
- 2014 – **Friedrichs** Anna, Julia A. Busch, Rohan Henkel, Rüdiger Heuermann, Christopher John,
- and Oliver Zielinski, “Measuring fluorescence by means of smartphones with the new Citclops Application”, Ocean Optics Conference XXII.
- 2014 - **Novoa**, S.; Wernand, M. R.; van der Woerd, H. J.. The modern Forel-Ule scale: a ‘do-it-yourself’ colour comparator for water monitoring. Journal of the European Optical Society - Rapid publications, Europe, v. 9, jul. 2014. ISSN 1990-2573.
- 2014 - **Simon**, C., Jaume Piera Fernandez. “Citclops: Citizen Observatory for Coast and Ocean Optical Monitoring”, Seventeenth Session of the GCOS/GOOS/WCRP Ocean Observations Panel for Climate.
- 2014 - **Simon**, C., Raul Bardají Benach, Jaime Piera Fernandez. “Water transparency estimation from citizen science underwater images”, Ocean Optics Conference XXII.

- 2014 - **Simon**, C., Raul Bardají Benach, Jaume Piera Hernandéz. “Water transparency estimation from citizen science underwater pictures”, Citizen's Observatories Event : Workshop and Open Conference.
- 2014 - **Wernand**, M.; Novoa, S.; van der Woerd, H.; Gieskes, W. (2014). A Centuries-long History of Participatory Science in Optical Oceanography: from observation to interpretation of natural water colouring. Histor. Meereskd. Jahrb. 19: 61-90. In: Historisch-meereskundliches Jahrbuch = History of Oceanography Yearbook. Deutschen Meeresmuseums (DMM): Stralsund. ISSN 0943-5697.
- 2014 - **Piera Fernandez**, J.; Raul Bardají Benach; Carine Simon. “Citizen Science and Do It Yourself Technologies: a new way to observe coastal environments”, 2nd International Ocean Research Conference.
- 2013 - **Bardají Benach**, R. and Piera J. “Low-cost moored instrumentation for citizens' education and participation in environmental stewardship”, OCEANS'13 MTS/IEEE, 2013..
- 2013 - **Bardají Benach**, R.; Zafra, E.; Piera, J. Estimating underwater light diffuse attenuation with low-cost devices: optimal sensor configuration analysis using radiative transfer models. In: "Martech 2013 5th International Workshop on Marine Technology". Girona: SARTI, 2013. URI: http://hdl.handle.net/2099/13852. ISSN: 1886-4864.
- 2013 – **Busch**, J. A., Allan Cembella, Margarita Fernández Tejedor, Jorge Diogène, Oliver Zielinski, “Enhancement of spatio-temporal coverage for HAB monitoring in the Ebro Delta, NW Mediterranean”, 3rd EOS Topical Meeting on Blue Photonics - Optics in the Sea (Blue Photonics 3).
- 2013 – **Friedrichs** Anna, Julia A. Busch, and O. Zielinski, “Approach for long-term observation of fluorescence in complex coastal waters by means of mobile phones”, YouMaRes 3 conference
- 2013 – **Henkel**, R. H., Julia A. Busch, R. Heuermann, D. Voß, Anna Friedrichs, K. Munderloh, O. Zielinski, “Mobile fluorescence sensing for citizens observatories”, 3rd EOS Topical Meeting on Blue Photonics - Optics in the Sea (Blue Photonics 3).
- 2013 - **Wernand**, M.R., A. Hommersom, H.J. van der Woerd. “MERIS-based ocean colour classification with the discrete Forel-Ule scale”. Ocean Science, 9, 477-487
- 2013 - **Novoa**, S., M. R. Wernand, H.J. Van Der Woerd. “The Forel-Ule scale revisited spectrally: preparation protocol, transmission measurements and chromaticity”. Journal of the European Optical Society.
- 2013 - **Novoa**, S.; Wernand, M. R.; Van Der Woerd, H. J. "The Forel-Ule scale revisited spectrally: preparation protocol, transmission measurements and chromaticity", Journal of the European Optical Society - Rapid publications, Europe, v. 8, aug. 2013. ISSN 1990-2573.
- 2013 - **Olivé**, J. [et al.]. Representing SensorML and O&M files in android clients. In: "Martech 2013 5th International Workshop on Marine Technology". Girona: SARTI, 2013. URI: http://hdl.handle.net/2099/13863. ISSN: 1886-4864.
- 2013 - **Ramírez-Pérez**, M. [et al.]. Size discrimination of inorganic suspended particles based on the analysis of hyperspectral attenuation measurements. In: "Martech 2013 5th International Workshop on Marine Technology". Girona: SARTI, 2013. URI: http://hdl.handle.net/2099/13853. ISSN: 1886-4864.
- 2013 - **Simon**, C., J. Piera. “Image processing for automatic estimation of water transparency using crowdsourcing data”, 3rd EOS Topical Meeting on Blue Photonics - Optics in the Sea (Blue Photonics 3).
- 2013 - **Simon**, C.; Piera Fernández, Jaume. Optimal pattern design for automatic estimation of water transparency through photograph using crowdsourcing data. In: "Martech 2013 5th International Workshop on Marine Technology". Girona: SARTI, 2013. URI: http://hdl.handle.net/2099/13928. ISSN: 1886-4864.

1.3.7. **Geographic information systems**

A result of the project related to GIS is the **transformation of multispectral remote-sensing images into the FU scale**. Temporal statistics of coastal water properties has been built from the long-term MERIS archive (an improved dataset of MERIS data coming from the ESA-funded CoastColour project) with the aim to support the interpretation of in-situ measurement by scientific instruments or by citizen-science methods. Thanks to a new algorithm, the FU and the chlorophyll concentration derived from the FU colour index are calculated.

Another result is the **creation of suitable data layers for citizen-science projects**. The catalogue of data layers is split into two logical sections:

- **Primary data**: citizen-science and other in-situ data as well as satellite observations.

Dataset title	Source
MERIS chlorophyll concentration observations	ESA ENVISAT archives
FU colour maps calculated from MERIS images	ESA ENVISAT archives + Citclops algorithm
Diffuse attenuation (transparency)	Data captured by low-cost buoys and sent via a Citclops mobile application
FU mobile app observation and photo	EyeOnWater - Colour app
Historic Secchi-disc archive	NIOZ/NOAA
Fluorescence	In-situ sensors
User/contributor profile	User-entered via web page / application

- **Derived data**: products of the interpretation (e.g., interpolation, validation) of primary data.

Dataset title	Source
Statistical aggregations of FU satellite maps	Algorithms developed by NOVELTIS taking a region and date range and returning a single image.
Time series of historic FU readings from satellite maps	Algorithms developed by NOVELTIS drawing on the MERIS FU historic archive.
FU interpreted from water photograph	NIOZ algorithm on incoming photo.

Another result is the integration of a **GIS subsystem** into a citizen-science project infrastructure. The major components related to this are as follows.

Spatial relational database. At the heart of the Citclops system is the relational database, comprising all observations, metadata, and auxiliary data such as user profiles and event logs. The database is central to the functioning of the GIS subsystem. The relational database is implemented using PostgreSQL with the PostGIS spatial extension. The PostGIS extension provides additional spatial (geometry) data types to the PostgreSQL database. These spatial data types are used in conjunction with a collection of spatial data operators allowing for a wide range of GIS operations including intersection, aggregation, and clipping from within the database itself. For example, limiting the extraction of observations to only those falling within one km of a given latitude/longitude coordinate can be achieved in a single SQL SELECT statement, and hence it is not required to be performed in the application layer by custom Citclops code.

Imagery archive. Alongside the relational database is the archive of image-based (raster) datasets, notably satellite observations and photographs taken by the smartphones as part of the FU measurement process. These datasets are not limited to coloured representations of satellite observations (e.g. maps), but also contain the physical values associated with each pixel for a range of properties including FU-scale, chlorophyll-a concentration and suspended matter. The raster datasets are stored in both NetCDF and GeoTIFF format; both formats are able to store geo-referenced grids containing floating point pixel values. FU water photographs are stored in their original Jpeg format. An important aspect of the imagery archive is that it is indexed by the relational database. For every image in the imagery archive, there is a representation in the database containing the footprint of the image, along with the date of observation and filename necessary to find the image in the imagery archive. This provides the ability for any system component to query a geographic point or area for the existence of imagery, and obtain the list of datasets corresponding to that request.

GIS services. The GIS services are a collection of modules written to perform services for the Citclops Data Explorer. These modules are implemented via RESTful web services. The following services were developed and are available to the public:

Time series extraction from MERIS data. This service returns the historic values for a certain variable for a given point or area between two dates. An example use for the data returned by this service is the validation of an incoming observation, to determine if it is within a reasonable range for that location and time of year. Another use is as input for an aggregation service returning a min, mean, max; this service acts as the data retrieval mechanism. The service takes one or more date ranges, allowing the user to specify a specific time of year over multiple years.

Aggregation services for MERIS data. This service returns the min, mean, and max values for a given variable for a point or area. It uses the "Time series extraction from MERIS data" service as its data source.

Smartphone image upload. In order to make the smartphone upload data more accessible, a service has been put in place accepting data from the smartphone application. This service accepts a zip file containing the photo and metadata and stores it in a directory made visible via a web server.

OGC services. These are services for the extraction/visualisation of Citclops data, based on well-known standards and protocols. The GIS and Citclops Data Explorer subsystems use them heavily: they are used within the Citclops Data Explorer for providing the client-facing applications with maps and data, but also serve as gateways for external systems such as SeaDataNet, INSPIRE, EMODnet and GEOSS to provide visibility of the Citclops database. The OGC services are primarily those sanctioned by the *Open Geospatial Consortium* (OGC), a standards body comparable to the *International Organization for Standardization* (ISO) for spatial data, and are used as follows:

OGC Web Map Service (WMS). The WMS service provides visualisations of raster data. The WMS server returns PNG or JPG renditions of data, according to an agreed colour scheme in the case of observed variables such as chlorophyll concentration. For the special case of FU dataset, a colour scheme has been implemented rendering the FU data with pixels coloured to match the appropriate value according to the FU colour scale. The WMS server is used by the Citclops Data Explorer to produce the necessary maps for the interactive map-based interface, as well as any mapping requirements of the mobile clients.

OGS Web Feature Service (WFS). The WFS service exposes point, line and area features stored in the relational database, including a standardised mechanism for filtering the data based on spatial and non-spatial attribute values. The WFS service is used for example to obtain the IDs of MERIS images over a given point for a given date, which could then be used to obtain maps containing that data from the WMS service. The WFS service is also used by the Citclops Data Explorer to position vector markers (clickable points) on the map, providing improved interactivity.

Citclops Data Explorer (DSS). The Citclops Data Explorer provides a graphical user interface in the form of a web mapping application that exposes the data collected and derived by Citclops. It is a consumer of the GIS subsystem. The Citclops Data Explorer uses certain GIS and interoperability services as sources for data by making requests either by HTTP requests or directly through imported modules. The web mapping application presented by the Citclops Data Explorer relies on the interoperability services, namely WMS and WFS, to provide images and points for the interactive map. The Citclops Data Explorer is the component that drives the data flow; it provides the services accepting observations submitted by users, including via smartphones, and executes the appropriate validation/publication steps that result in new observations being deemed ready for use by the other system components.

Another result is the **transformation of satellite data to transparency and water composition**. Specifically, this consists in the conversion from MERIS surface reflectance to the FU-index scale[3], with the additional step of deriving the chlorophyll concentration from the FU colour. The data generated are the FU and FU-derived Chl bands, which are calculated on the CoastColour data using the original 300-m spatial resolution.

[3] The FU index ranges from 1 to 21 (indigo-blue to cola-brown, respectively). This colour index roughly indicates different types of natural waters / aquatic ecosystems: oligotrophic, mesotrophic, eutrophic like the open ocean, coastal zones, tidal flats or river, and lakes.

The process to obtain the FU scale is listed below and illustrated in Figure 26:

1- download of the water-leaving reflectance (level 2 R – L2R) from the CoastColour website;
2- selection of the parameters and the areas of interest;
3- reprojection of the data on a fixed grid and removal of invalid pixels;
4- FU and chlorophyll-concentration calculation from the gzip compressed data
   ➔ attainment of the FU and chlorophyll-concentration bands in an output NetCDF file;
5- upload of the processed FU and chlorophyll-concentration data to the Citclops server.

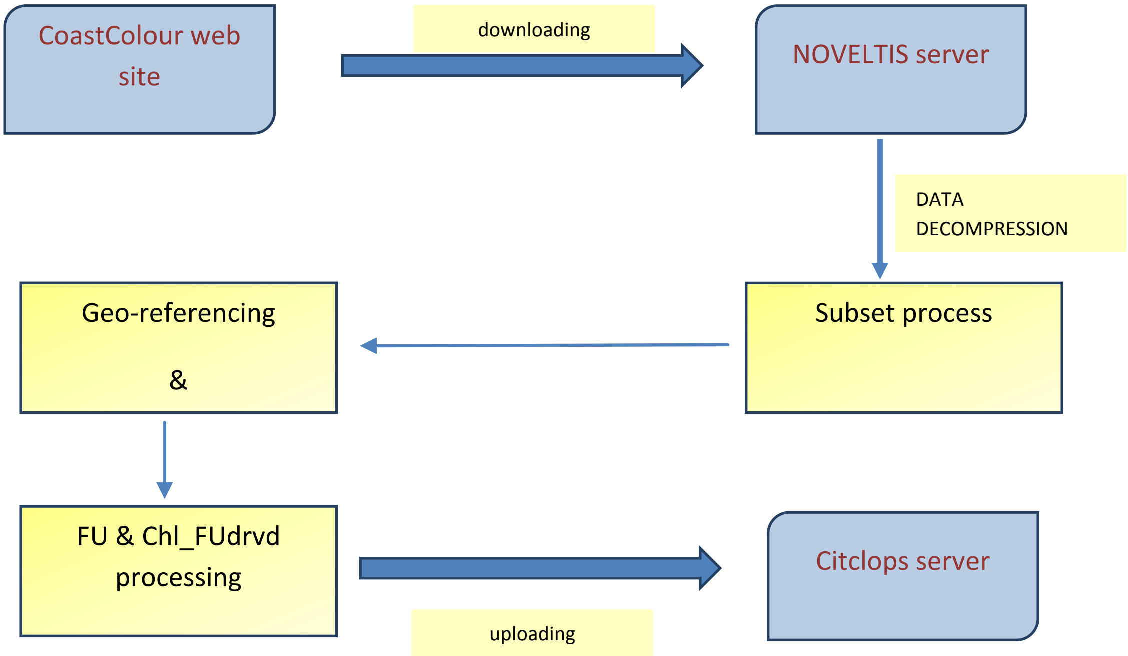

Figure 26. Diagram of the CoastColour data (MERIS images) transformation process to FU and chlorophyll concentration

Finally, another result is an **algorithm for GIS-related data validation and quality control**. An important aspect in using citizen science to collect environmental data is quality control. The data are coming from various sources and are collected under different conditions, which will influence the quality of the observations and their use. To facilitate wider use of these data, it is required to validate the observations by means of data quality control procedures and a tie-in with independent satellite-based and ground-based observations. Citclops carried out a characterisation of bias and standard errors of low-cost sensors and information from citizen-science apps.

<u>The Ebro delta case study</u>. Changes in water colour are linked to processes of concern to society, including algal blooms. In order to motivate citizens to get engaged in environmental monitoring and to improve their environmental-science knowledge, measurement tools for citizens have been developed within Citclops. In one of Citclops test areas, the Ebro delta, NW Mediterranean Sea, measurements of water colour with the FU scale revealed colour changes over short distances and time frames, indicative of fast dynamics of phytoplankton in the area. The typical seasonal pattern of phytoplankton proliferations was reflected well by FU colours as retrieved from satellite data (MERIS full resolution data). The results show that a simplified classification of natural waters by its colour enhances our understanding of spatio-temporal dynamics in the Ebro Delta. Hence, such measurements can complement more accurate in-situ observations that allow the identification of harmful algal taxa. Thereby, Citclops observations support phytoplankton surveillance for human health and food safety. Direct links to environmental issues strongly motivate the general public to engage in environmental surveillance and stewardship, and to support local monitoring efforts. The Citclops's MERIS FU-colour conversion and extraction service for the Ebro Delta delivered a good overview on water colour changes over time. It is an indication of what we might expect a citizen-science app could deliver. These citizens' observations do not cover a standard grid, but are mainly positioned along the shore line. And that is exactly where the MERIS data are most corrupted and so the two sources are complementary. Also, the in-

situ dataset of measured FU values, which represents a type of measurements taken by citizens, revealed more details than the MERIS data.

1.4. Potential impact and the main dissemination activities and exploitation of results

At its most basic level the Citclops project contributed to citizen awareness of water column state as indicated by colour and transparency, and to a realisation of scientific language as an aid. In TCD/Coastwatch fieldwork, for example, citizens were asked to describe sea by temperature, colour and transparency. As they struggled with verbal answers along 'cold, greenish and not so clear' lines, the offer of scientific language (a number to identify a kind of sea colour; transparency as a measured distance you can see an object under water) was invariably met with 'how clever and useful'. This opened the door to introduce issues such as: why there are different kinds/shades of colour; and the existence of plankton and its ecosystem services (which was news to the vast majority of adult citizens including third level students outside the life sciences). This in turn made the use of apps to record water colour and transparency information something potentially useful and worth downloading and trying.

Citclops produced then major potential **impacts both in the research field and the citizen-science environment**. By taking into account the needs of decision makers and local actors (citizen communities), and by designing an information-delivery system based on the results of citizen-science monitoring, Citclops contributed to the effective implementation of EU directives, such as, for instance, the Bathing Water Directive, whose general provisions include that the public should receive appropriate and timely information on results of the monitoring of bathing-water quality and risk-management measures to prevent health hazards, especially for predictable short-term pollution or abnormal situations. Citclops's tight focus on case studies enabled depth of analysis and understanding of the needs for economically-sustainable water monitoring. In order to achieve its impact, Citclops followed a dissemination strategy targeted according to the types of audience, ensuring fruitful results and cost efficiency. Much attention has been given to the interaction with key actors and stakeholders, ensuring the value of the final results and recommendations. The guidelines developed in the project will facilitate citizen-science--monitoring implementation at all levels (European, national, regional and local). Particular attention has been also given to the issues of knowledge management and intellectual property.

Main dissemination activities offered to citizens during the project execution-time are presented in Table 1.

Over the course of three years, Citclops developed innovations leading to many achievements/results, which have been described in earlier sections and are summarised as follows:

- **novel, inexpensive measuring devices** to collect water colour, transparency and fluorescence observations;
- **apps for smart phones to collect these observations;**
- **new and improved algorithms** to process citizen-science data: images of sea colour, transparency data from DIY buoys, water-fluorescence data;
- an internet **platform** to collect and check the quality of the data and to deliver information to citizens and researchers;
- **training/education/outreach** material to explain water colour, plankton and new ways of collecting and interpreting measurements related to the quality of coastal waters.

At the end of the EC funding phase, the objectives of the project have been reached; the technology is mature; the project experienced interest amongst diverse communities; and **exploitation of results** has started to involve targeted stakeholders from the following segments:

- **government / authorities / decision makers**;
- **citizens**;

- **industry**;

- **researchers**.

The first feedback from these segments/communities is that the citizen science promoted by Citclops is a valuable new paradigm, worth to be developed not only for coast and ocean monitoring, but also for inland-waters monitoring. As the project drew to a close in Ireland, the Irish EPA had added a water transparency monitoring condition to its *dumping dredge spoil at sea* licenses, the national school sea training vessel had incorporated Citclops teaching into its core environment training module and the Irish Marine Institute was planning a note on the EyeOnWater app for aquaculture farmers around Ireland. A Wexford tourist resort has added a note encouraging app use and Citclops materials to its new coastal trail to introduce visitors to soft clean humic acid rich bog water which enters the sea and is no longer to be mistaken for pollution.

A presentation of fieldwork methods and app at the annual geography and biology secondary teacher in-service training (September 2015), supported by the Irish national Department of Education, has lead to uptake by several schools.

The targeted categories of end-users (customer segments) of the Citclops Data Explorer, apps, instruments and social networks, from an exploitation perspective, are listed in Table 2. In bold characters are the stakeholder categories to which the Citclops services have been already presented and from which feedback has been collected to assess their interest in Citclops and their possible willingness to adopt its results.

In the rest of this section, exploitation plans based on the feedback collected are described in deeper details.

Table 1. List of events with citizens´ engagement

Actions for stakeholder engagement PM 1-36				
#	**Date Time**	**Location**	**Group**	**Objective/Outcome**
88	September 25, 2015	Barcelona, Spain	General public, researchers	The KdUINO buoy and Citclops have been presented during the European Researchers' night as part and context of the Musical Tentacle prototype (also presented during the Sónar+D conference in June 2015).
87	September 23, 2015	Ratheniska Portlaoise, Ireland	General rural public of all ages	The national ploughing championship is the largest rural event in Ireland and includes many environmental information stands. A Citclops's shared stand with national environmental groups was popular.
86	September 21-25, 2015	Toulouse, France	Scientists	Presentation of Citclops results at the annual EUMETSAT conference
85	September 21-25, 2015	S and W of Ireland schools	Secondary schools and teachers	Skippers and crew members of the sail training vessels, trained up by Coastwatch/TCD, visited schools and gave a preview of their 2016 sail and teach programme, featuring Citclops methods.
84	September 21-25, 2015	Lisburn Good Beach Summit, Northern Ireland	Local stakeholders , government and agencies	Short Citclops presentation to inform the meeting about the project and new app. Good interest from NI environment agency particularly.
83	September 18, 2015	Vienna, Austria	Program managers	Initial meeting of the Top Citizen Science Steering Board
82	September 15, 2015	Bulloch and Howth harbour	Fishermen	Introduced the new EyeOnWater app and showed/donated Citclops materials set. Some fishermen now take out visitors and like extra gadgets when waiting for fish to bite. Others wanted a tool to record dredging plume as harbour dredge and dumping at sea applications had been lodged.
81	September 9-11, 2015	Lisbon, Portugal	Secondary school teachers	Presentation of Citclops methods and ancillary plankton information as class and fieldwork teaching module. Some has since been translated and is being used. Results meeting planned for March 2016.
80	August 24 - 28, 2015	Sant Carles de la Ràpita, Spain	Next generation citizens	Scientific summer camp, including TrandiCam pictures
79	August 21-23, 2015	Galway and research vessel Galway Bay and Clew Bay	Third level students, environmental NGOs and advanced citizen scientists	University summer school: Blue Info-days style fieldwork. This was inspired by the Wexford Blue Info-days.
78	July 26, 2015	Galway Docks 1-5, Ireland	General public	Spirit of Oysterhaven: demo of Citclops materials on board as part of open boat
77	July 21, 2015	N Dublin bay shore, Ireland	Next generation citizens	Darndale and Coolock kids' camp. Sea life plankton as part. FU scale. Lead by Dave Tilly.

76	July 18 + 19, 2015	Dublin St Anne's Park, Ireland	General public	Rose Festival, hand out Citclops book marks and 'Make map' materials, demos using grass and blue sheet as too far from shore, talk to interested individuals.
75	July 16, 2015	Howth, Ireland	General public	Yacht club drainage scheme info. Hand out Citclops book marks and join us to make map, talk to interested individuals.
74	July 10 + 11, 2015	Cork, Ireland	General public	Our Ocean Wealth Conference & Exhibition. Hand out Citclops book marks and join us to make map, talk to interested individuals.
73	July 9 – September 6, 2015	Sant Carles de la Ràpita, Spain	Divers	Scientific diving, including TrandiCam pictures.
72	July 6, 2015	Rush shore + indoor, Ireland	General public	Demo of Citclops materials and info on plankton and how shore life depends on plankton for food, reproduction etc.
71	June 28, 2015	Bolton Street Dublin, Ireland	General public	Spatial planning workshop, handed out new Citclops bookmarks and encouragement to try/discussions in the breaks.
70	June 24, 2015	Bull Island Dublin Biosphere launch, Ireland	General public	Handed out new Citclops bookmarks on the shore. Shore walk macro algae, biomass of greens as nutrient enrichment indicator Joyce – bay snot green use FU scale.
69	June 23, 2015	Ballymoney Co Wexford, Ireland	Crew + trainees Spirit of Oysterhaven boat	Demo of all parts of Coastwatch + Citclops survey
68	June 21, 2015	Wilhelmshaven, Germany	Students	Student training. Participation in Ocean Sampling Day 2015.
67	June 21, 2015	Ireland	General public	Participation in Ocean Sampling Day 2015.
66	June 20 + 21, 2015	Moville Co Donegal, Ireland	General public & next generation citizens	Citclops plankton workshop, plankton presentations and fieldwork with 'Citclops Plus' material set.
65	June 18 – 20, 2015	Barcelona, Spain	General public	During the congress Sónar+D it has been shown the Musical Tentacle, a version of the KdUINO buoy connected to a visualization and sonification module. The leaflets about the project have been distributed between the general public and there have been several presentations of the project during the event.
64	June 17 + 18, 2015	Galway, Ireland	General public	EPA Water conference, handed out Citclops forms and EPA gave a good plug for all to try it.
63	June 5, 2015	Navy Base Cork, Ireland	General public	ECOWELL conference, plenary presentation about water quality parameters and Cork Harbour with overview of official monitoring & citizen science. Citclops as one tool.
62	May 30 + 31, 2015	Llançà, Spain	Kayakers	Participation in "Days of Kayak and Environment", Llançà, Spain. Theoretical and practical activities on transparency and colour (Forel-Ule, Secchi Disk, TrandiCam).

61	May 30, 2015	Westport Quay and boat Co Mayo, Ireland	General public & next generation citizens	Demo use for families on pier and later boat. Encourage scout leaders to make Secchi discs with groups.
60	May 27 + 28, 2015	Ennis Co Clare and shore, Ireland	Lifeguards	Life Guard training: Teach a Water and Environment Citclops module for Lifeguards to use on the shore – alert, sampling, ID algal blooms & jellyfish. Env. Staff: 6 staff joined in, responsible for bathing water &WFD monitoring.
59	May 25, 2015	Duncannon and Booley bay Waterford estuary, Ireland	Next generation citizens	Primary school presentation: sea water mysteries unravel, use of Secchi disc, hands on demos, shore safari, who needs plankton. Try Citclops material.
58	May 24, 2015	Dublin Bay, Ireland	General public	Kite Surfer Festival, inform the public & water sports community about plankton/Citclops.
57	May 17, 2014	Ballymoney, Co Wexford, Ireland	Irish Austrian Society	Inform mixed group about plankton and citclops app.
56	May 11-13, 2015	Barcelona, Spain	Researchers	4th EOS meeting on Blue Photonics
55	April 25 – 26, 2015	Wexford, Ireland	General public, including next generation citizens	Second Blue Info Days. Consisted of a mix of short talks, demos and hands on trials, lots of fieldwork and fun water events.
54	March 30 – April 1, 2015	Llançà, Catalonia, Spain	Kayak community	Citizen training during sea kayak symposium in Llançà. Measurements of water colour with different devices: transparency with KdUINO, and algal fluorescence with new smart phone adapter.
53	February 22 – 27, 2015	Granada, Spain	Researchers	Citclops at ASLO conference
52	February 10, 2015	Bremerhaven, Germany	Young graduate students (POLMAR graduate school of Helmholtz)	Talk: Citclops - Citizen science project for coast and ocean optical monitoring with smart phones" by J. Busch to inform young marine researchers about citizen science and Citclops.
51	January 26 – 27, 2015	Osnabrück, Germany	Actors of nature conservation, national heritage protection, environmental education and interested citizens	Event: "Citizens between engagement and science- Citizen Science: perspectives, challenges and constraints"
50	December 31, 2014 – 21 April, 2015	Barcelona World Race	Professional sailors	Making the collection of color samples of seawater through Citclops app by BWR skippers. This process involves all of the boats taking part in the Barcelona World Race 2014/15. In this edition of the race there are eight teams formed by two skippers (see Figure 14). It was decided to distribute a smartphone with the Citclops app installed to each team. There have been also some introductory and test sessions with the race teams.
49	December 28, 2014	Barcelona, Spain	Professional sailors	Plenary meeting and presentation of the Citclops project and Citclops app to the BWR skippers and BWR TV.

Three

48	December 15, 2014	Wien, Austria	Students, researchers	Presentation of Citclops at Sparkling Science Workshop
47	December 4th, 2014	Brussels, Belgium	Researchers, decision makers	Open conference: citizens' observatories. Empowering European society
46	December 3rd, 2014	Brussels, Belgium	Researchers, decision makers	Workshop on Citizens Observatories Projects
45	December, 2014	Barcelona, Spain	Professional sailors	Field test on the "One Planet One Ocean" IMOCA sail boat together with skippers.
44	November 1, 2014	Amsterdam, The Netherlands	General public	Museum night. Maritime museum Amsterdam, including measurements of paintings on colour of painted water.
43	October 25 – 31, 2014	Portland, Maine	Scientists	Citclops at Ocean Optics Conference 2014
42	October 4, 2014	Texel, The Netherlands	General public	Open Day at NIOZ, including presentation Seas of colour and hands-on experiences for Citclops methods (App, Secchi disk, Forel Ule Plastic scale) with Marcel Wernand and Lissie de Groet (NIOZ) on jetty.
41	October 3, 2014	Hannover, Germany	General public	German Unification Day. Citclops was presented during this event in a booth, but also hands-on experiences for the general public were provided at lake "Maschsee".
40	October 2-3, 2014	Texel, The Netherlands	Policy makers and water managers	Presentation of Citclops at Noordzeedagen (Dutch national symposium of North Sea policymakers). Ad hoc campaign for the participants to collect data from the Texel ferry.
39	October 2014 - May 2015	Crossing Atlantic ocean to Caribbean, Panama & Cuba	School kids from Lietz Inernat, Wittbülten, Spiekeroog	High Seas High School. Students experience a "sailing classroom" on gaff-rigged schooner Johann Smidt. Citclops provided Secchi-disk and Forel Ule plastic scale and measurements are coordinated with on-board teachers. Unfortunately, there was no smart phone on-board, which would have allowed the use of the Citclops App.
38	September - October	Range of 15 smaller training events	Tidy Towns, regional Coastwatch groups, schools and others who requested training	Show how the Coastwatch survey and Citclops work and provide some initial introduction to water colour and transparency.
37	September 28, 2014	Tralee Wetland Centre	Coastwatch surveyor and third level student training event	Provide training for teachers, wetland centre staff and 3rd leverl students for project work. Developing health and safety protocols and guidance for optimum teaching facilities (here several water bodies ranging from eutrophic with algal bloom at time of survey to clear water).
36	September 15, 2014	Carlingford Centre	Coastwatch regional coordinator training event all Ireland and press launch	Show how Citclops materials are to be used and in collaboration with the EPA provide plankton information to regional coordinators as knowledge disseminators.

business cases have been identified for the exploitation of results:

35	September 13, 2014	Monument Day: On Board TESO ferry in Netherlands	Tourists	Informative video about the colour of the ocean and Citclops.
34	August 5 – 6, 2014	Aurich, Germany	Sports group (sea kayak association)	Citizen training. Use of Citclops tools (Secchi disk, plastic FU scale, App) from kayak. Special emphasis on water-proof housing.
33	August 2014	Greater Dublin Area, Wicklow and Wexford	General public, youth groups and life guards	Testing draft Citclops survey materials for possible use in the autumn Coastwatch survey and testing inflow nitrate levels to introduce nutrients and algal blooms.
32	July 2014	East and South coast Ireland	General public on bathing beaches	Test base knowledge and understanding of colour and transparency and trial FU scale and simple field methods to check water sediment load.
31	June 26 + 27, 2014	Scheepvaartmuseum Amsterdam, Netherlands	Citizens	NIOZ staff is present on the RV ‘Pelagia’ at the Scheepvaartmuseum Amsterdam to demonstrate water colour measurements with and without the Citclops App.
30	June 21, 2014	Wilhelmshaven, Germany	Students	Student training. Participation in Ocean Sampling Day 2014.
29	June 19 – 20, 2014	Wilhelmshaven, Germany	Senior Citizens	Citizen training. Use of Citclops tools
28	June 14 + 15, 2014	Barcelona, Spain	General public	Participation in Science Festival, Barcelona, Spain. Explanations, demonstration of use of the KdUINO.
27	June 2 -11, 2014	ICM, Spain	High school pupils	Theoretical and practical workshop on transparency and the KdUINO for high school pupils.
26	May 29, 2014	Barcelona, Spain	General public & next generation citizens	Barcelona Citizen Science Day, KdUINO
25	May 18, 2014	Bremen, Germany	General public	European Maritime Day including individual short training
24	April, 14, 2014	Zeeland, The Netherlands	Water managers	Pilot applying Citclops prototype app and camera photos during monitoring cruise of Dutch Rijkswaterstaat in Volkerak Zoommeer with Univ. Amsterdam and Mr Eugene Daemen (Rijkswaterstaat)
23	April 2014	Internet	Citizens	First Citclops - Citizen water monitoring App prototype is released.
22	April 2014	Barcelona, Spain	Next generation citizens	KdUINO training event at CSIC
21	End of March 2014	Wadden Sea Centre Wilhelmshaven	Citizens	Integration of Citclops exhibit to permanent exhibition
20	March 17 – 19, 2014	Oldenburg, Germany	Citclops project partners	Meeting of the Citclops consortium.
19	March 15 + 16, 2014	Wadden Sea Centre Wilhelmshaven, Germany	General public	First Blue Info Days, Hands-on practical day. In depth information on methods and hands-on training.

18	March 13, 2014	Utrecht, The Netherlands	National Symposium on water quality monitoring for regional water managers	Citizen involvement in decision making and coordination with local policy makers and municipalities.
17	February 24, 2014	Delft, The Netherlands	Professionals	Introduction of Citclops to association of professional line and pole fishermen, VBHL(Vereniging van Beroepsmatige Handlijnvissers)
16	February 20 – 23, 2014	Catalonia, Spain	Schools	Different schools of Catalonia. Theoretical and practical workshop on transparency and the KdUINO for high school pupils.
15	February 18 - 21, 2014	Deltebre, Sant Carles de la Ràpita, L'Ametlla de Mar, Spain.	Schools	Workshops in three different schools to explain the principles of building the KdUINO.
14	February 2014	Internet	Citizens	New Website is online.
13	December 17, 2013	Delft, The Netherlands	Water managers	Introduction of Citclops to Dutch national water management centre (Rijkswaterstaat) and setup of pilot monitoring case in Zeeland
12	November 19 – 20, 2013	Institute of Marine Sciences ICM-CSIC, Barcelona, Spain	Citizens	Open Day at ICM-CSIC. Short introduction on our ongoing projects to the visitors (particularly Citclops), with a demonstration of the DIY principle of KdUINO.
11	October 2013	All around Irish coast	Citizens	Coastwatch survey – basic shore audit
10	September 13, 2013	Wicklow Harbour, Co Wexford	Citizens	Training event in cooperation with Wicklow county council. Audit of sampling point characteristics and health and safety issues.
9	September 11-13, 2013	Oldenburg, Germany	Researchers	Citclops at YouMaRes 4 from coast to deep sea: multi-scale approaches to marine science
8	August 30 – 31, 2013	National Heritage Park Wexford and Wexford Coast	Teachers, environmental NGOs, local authority environmental officers, anglers and fishermen	Participatory training seminar and fieldtrips including one sea angling charter boat
7	August 29, 2013	Lake Grevelingen, The Netherlands	Citizens	Identify interests & constraints of public and for comparative measurements of water colour.
6	June and July 2013	TCD Dublin, Wicklow and Dublin Coast Ireland	Citizens	First test of bio-optical properties measurements for integration in Coastwatch survey.
5	May 27 – 31, 2013	Research vessel Otzum, River Elbe, Germany	Researchers	Research trip on river Elbe, Germany. Test of portable fluorescence devices in combination with a PDA and Pidian as pre-stage to mobile phones.
4	April 30, 2013	Nationalparkhaus Wittbülten, Spiekeroog, Germany	School class of the Hermann-Ehlers-Schule Oldenburg	School class course, Hermann-Ehlers-Schule Oldenburg: Introduction of bio-optics to next generation citizens. Test of feasibility of questionnaire and bio-optical measurements for children of this age class.

3	March 18 -20, 2013	Texel, Netherlands	Researchers	Citclops at 3rd EOS Topical Meeting on Blue Photonics - Optics in the Sea
2	October 8-12, 2012	Glasgow, Scotland	Researchers	Citclops at Ocean Optics Conference 2012
1	December 2012	Internet	Citizens	Project website is available.

1. **Monitoring projects**, driven by the information requirements of **researchers** (citizen science) and **decision makers** (participatory monitoring); funded by government agencies in relation to law enforcement and the improvement of environmental policies.
2. **Communication/outreach platform**, for educational/lobbying use by a (regionally-focused) organisation or group of citizens interested in reporting and sharing water-quality data; funded by advertisement, or by the user group, or by subscription contributions.
3. **AI-based monitoring technologies**, providing private companies with **advanced water information** or with **water-quality measuring** capabilities; funded by private companies.

With respect to dissemination activities and exploitation of results, the aim was to trigger action to increase the impact of citizen science. A common problem encountered when publishing results was that, apart from the specific days in which they were in the news, some of them, especially in the form of scientific papers, landed or will land out of view behind a paywall. Also, once some research result was published, it became old news to journalists, social media and the editors who published it. Years of research are, at the end of the project, at risk of being handled like a disposable good, despite being created to be a durable good, one that would benefit the target users (society) as long as possible. Citclops's scientists will return with other publications, systems and apps only after years of additional work in new projects, again drawing a few days of attention. At this rate, we will likely fail to address the major challenges of increasing the impact of citizen science. By using news and social media as our principal messengers of scientific progress, we have a mismatch in speed and an ineffective communication system. Across the landscape, we substitute the new for the important, and this will cause public science-literacy to falter. When expert opinions quietly slip by, it is more difficult for decision makers to carry out their duty to protect public welfare.

Of course, important scientific findings may live on in web pages, synthesis papers and open-access databases. Smart journalists, museums and citizen voices might keep their focus on the important issues, but it is unlikely to hear much more in the media, because old science is old news.

The fact something has always been done a certain way is no proof that it is effective. Until the 20th century, we thought that there was one way to do science. Now we are in a situation in which, thanks to citizen science, we can clearly focus on (and grow a healthy society around) what is important and true; and, in the world of science communication, this needs to be accompanied by efforts to tame current obsession with what is new. And this is why the communication services of the European Commission need to continue their efforts, when they write, post or speak about today's science news, to consider that the major research landings of last months or years, such as Citclops's, may still carry much weight.

Table 2. Citclops end-users

End-user category	Typical end-user	Information/results Citclops provides or can provide
Government / authorities / decision makers	• **Decision makers in charge of day-to-day management of surface-water quality** • **Persons responsible for the development of monitoring programmes** • **Persons responsible for reporting and policy concerning water-quality legislation and directives**	• Surveillance of turbidity plumes and algal blooms (related to law enforcement) • Monitoring of ecosystem status and help to quantify algal bloom characteristics (maximum, median, duration) • Data about bathing water quality, and algal bloom early warning (related to tourism) • Monitoring-program design (deciding where and when to measure)
Citizens	• Professionals: harbour masters, government inspectors, **fishermen**, fish farmers • Non-professionals: **students, volunteer observers (e.g., Coastwatchers), tourists, vacationers, schools** • NGOs, associations	• Help to predict (*nowcast*) water properties for touristic/recreational activities (e.g. diving, fishing) • Help to understand natural and anthropogenic variations in optical properties of water systems (for associations, schools)
Industry	• **Artisan fishing** • Aquaculture • Fisheries • Petrochemical plants (oil-spill management) • Dredging industry	• Help to predict (*nowcast*) water properties for professional activities (e.g. aquaculture, fishing) • Help to monitor turbidity plumes • Help to predict (*nowcast*) risk of massive algal blooms
Researchers	• **Environment researchers**	• Easily accessible data series

1.5. Address of the project public website, if applicable as well as relevant contact details

Citclops's results and information on Citclops-related activities can be accessed at the following project public websites:

- **Main websites** [http://www.citclops.eu/] [http://www.eyeonwater.org/] [http://citclops-data-explorer.herokuapp.com/]
- **Google+** [https://plus.google.com/+CitclopsEu]
- **Google+ community** [https://plus.google.com/communities/113633358709457603658]
- **Facebook** [https://www.facebook.com/groups/citclops/]
- **Pinterest** [http://pinterest.com/citclops/sea-color/]
- **LinkedIn** [http://www.linkedin.com/groups/Citclops-4788061]
- **Leaflets, posters** [http://www.citclops.eu/the-project/leaflets-posters-and-brochures]
- **Citizens' observatories website** [http://www.citizen-obs.eu/]

Relevant contact details and list of partners:

- **Luigi Ceccaroni** (scientific coordinator; PI; leader of WP on data interpretation and knowledge-based systems integration): [https://www.linkedin.com/in/luigi]
- **Jaume Piera** (leader of WP on crowdsourcing technologies for the monitoring of the colour, transparency & fluorescence of the sea): [https://www.linkedin.com/in/jaume-piera-15819027]
- **Marcel Wernand** (leader of crowdsourcing technologies for the monitoring of the colour of the sea and of WP on preparation for exploitation and demonstration): [https://www.linkedin.com/in/marcel-wernand-73286683/en]
- **Oliver Zielinski** (leader of crowdsourcing technologies for the monitoring of the fluorescence of the sea): oliver.zielinski@uni-oldenburg.de
- **Julia Busch** (leader of WP on citizens' education and participation in environmental stewardship): julia.busch@uni-oldenburg.de
- **Karin Dubsky** (co-leader of WP on citizens' education and participation in environmental stewardship): [https://www.linkedin.com/in/karindubsky/]
- **Peter Thijsse** (leader of WPs on data management and interoperability portal, and on dissemination and standardisation): [https://www.linkedin.com/in/peterthijsse]
- **Eric Jeansou** (leader of WP on GIS analysis and data-layers integration): [https://www.linkedin.com/in/eric-jeansou-ba60a610a]
- **Meinte Blaas** (relation with decision makers): [https://www.linkedin.com/in/meinteblaas]
- **Hans Van Der Woerd** (leader of quality control): [https://www.linkedin.com/in/hans-van-der-woerd-59122510]
- **Filip Velickovski** (leader of software development of the Citclops Data Explorer): [https://www.linkedin.com/in/filip-velickovski-8ba2883b]
- **Raúl Bardají** (leader of software development of the KdUINO): [https://www.linkedin.com/in/raúl-bardají-73139733/en]
- **Joan Mas** (contact for contractual issues): joan.mas@eurecat.org

- **Eurecat** [http://eurecat.org/]
- **Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC)** [http:// www.icm.csic.es/]
- **Carl von Ossietzky University Oldenburg** [https://www.uni-oldenburg.de/en/]
- **Royal Netherlands Institute for Sea Research (NIOZ)** [http://www.nioz.nl/home_en]
- **Kinetical Business S.L.** [http://www.kinetical.com/]
- **TriOS Mess- und Datentechnik GmbH** [http://www.trios.de/en.html]
- **Mariene Informatie Service MARIS BV** [http://www.maris.nl/]
- **Noveltis SAS** [http://www.noveltis.com/en/]
- **Trinity College Dublin (Coastwatch Europe)** [http://coastwatch.org/europe/]
- **Stichting VU/VUmc** [http://www.vumc.com/]
- **Deltares** [https://www.deltares.nl/en/]

2. Use and dissemination of foreground

2.1. Section A (public)

Table 3 List of scientific (peer reviewed) publications

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
Nº	**Title**	**Main author**	**Title of the periodical or the series**	**Number, date or frequency**	**Publisher**	**Place of publication**	**Year of publ.**	**Relevant pages**	**Permanent identifiers[4] (if available)**	**Is/Will open access[5] provided to this publication?**
1	The history of subsea optics	Wernand M. R.	Subsea optics and imaging, Woodhead Publishing Series in Electronic and Optical Materials	No. 46	Woodhead	UK	2013	50	ISBN-13: 978 0 85709 341	no
2	A Centuries-long History of Participatory Science in Optical Oceanography: from observation to interpretation of natural water colouring	Wernand, M. R.	Historisch-meereskundliches Jahrbuch = History of Oceanography Yearbook	Jahrb. 19	Deutschen Meeresmuseums (DMM)/ German Oceanographic Museum	Stralsund	2014	61-90	ISSN: 0943-5697	no
3	The Forel-Ule scale revisited spectrally: preparation protocol,	Novoa, S.	Journal of the European Optical Society - Rapid publications	v. 8	JEOS	Europe	2013	8	ISSN: 1990-2573	yes

[4] 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).
[5] 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.

	transmission measurements and chromaticity									
4	The modern Forel-Ule scale: a ‘do-it-yourself’ colour comparator for water monitoring	Novoa, S	Journal of the European Optical Society - Rapid publications	v. 9	JEOS	Europe	2014	10	ISSN: 1990-2573	yes
5	WACODI: A generic algorithm to derive the intrinsic color of natural waters from digital images	Novoa, S.	Limnology and Oceanography: Methods	25 SEP	Wiley	Europe	2015	15	DOI: 10.1002/l om3.10059	yes
6	True Colour Classification of Natural Waters with Medium-Spectral Resolution Satellites: SeaWiFS, MODIS, MERIS and OLCI	Woerd, H.J.	Sensors	Volume 15, Issue 10, 9 Oct.	MDPI AG	Switzerland	2015	18	DOI: 10.3390/s1510 25663	yes
7	The ocean sampling day consortium	Kopf, A.	GigaScience	4:27	BioMed Central	Switzerland	2015	1-5	DOI 10.1186/s1374 2-015-0066-5	yes
8	Subsea optics: an introduction,	Zielinski, O.,	Subsea optics and imaging, Woodhead Publishing Series in Electronic and Optical	No. 46	Woodhead	UK	2013	3-16	ISBN-13: 978 0 85709 341	no
9	Optical assessment of harmful algal blooms (HABs)	Busch, J.A.	Subsea optics and imaging, Woodhead Publishing Series in Electronic and Optical	No. 46	Woodhead	UK	2013	171-212	ISBN-13: 978 0 85709 341	no
10	Citizens and satellites: assessment of phytoplankton dynamics in a NW Mediterranean aquaculture zone	Busch, J. A.	Journal of Applied Earth Observation and Geoinformation	In press	Elsevier		2015		DOI: 10.1016/j.jag.2 015.11.017	no
11	Low-cost moored instrumentation for citizens	Bardají, R.	Proceedings of MTS/IEEE OCEANS-Bergen	2013	IEEE	Norway	2013	1-3	DOI: 10.1109/OCEA NS-Bergen.2013.6 608176	no

Table 4 LIST OF DISSEMINATION ACTIVITIES

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[6]	Main leader	Title	Date/Period	Place	Type of audience[7]	Size of audience	Countries addressed
1	*Instruction video*	*NIOZ*	*Seas of colour*	*2014*	*Texel, NL*	Researchers, citizens, policy makers, media	-	Europe/International
2	Exhibition	NIOZ	Citizen's scientists and smartphones: Measuring the colour of water'	May-Nov 2015	Fortress Kijkduin, Den Helder, NL	Civil Society	-	Netherlands
3	*Fair*	*NIOZ*	Observatory for Coast and Ocean Optical Monitoring; Participatory Science and the Colour of natural waters.	*April 2015*	Hannover Messe, Germany	Community, Civil Society, Policy Makers, Medias	-	Europe
4	Museum/ Exhibition	NIOZ	Instruction of Citclops app and measurement on marine paintings in Maritime Museum Amsterdam	1 Nov 2014	Maritime museum, Amsterdam, NL	Civil Society	-	Netherlands
5	Conference	NIOZ	Ocean Optics	08 Oct 2012 - 12 Oct 2012	Glasgow, Scotland, UK	Scientific Community	350	International
6	Conference	NIOZ & UNIOL	Ocean Optics	October, 25th – 31st, 2014	Portland, Maine, US	Scientific Community	350	International
7	Conference	NIOZ & UNIOL	Blue Photonics 4	May, 11th – 13th, 2015	Barcelona, Spain	Scientific Community	80	Europe, International
8	Conference	NIOZ & UNIOL	Blue Photonics 3	March, 18th – 20th 2013	Texel, NL	Scientific Community	80	Europe, international

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[6] 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.

[7] 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).

9	Conference	UNIOL	YouMarRes	September, 11th – 13th, 2014	Oldenburg, Germany	Scientific Community	150	Germany
10	Other, Press release, & popular press	UNIOL	Blue Info Days	March 15th – 16th, 2014	Wilhelmshaven, Germany	Scientific Community, Civil Society, Policy Makers, Medias	60	Germany & Europe
11	Presentations	UNIOL	PhD-course	May, 25th – 31st, 2014	Askö, Sweden	Scientific Community	20	Europe
12	Other	UNIOL	European Maritime Day	May, 19th – 20th, 2014	Bremen, Germany	Civil Society	1,200	Europe
13	Workshops	UNIOL	Sea kayak workshop	August, 5th – 6th, 2014	Aurich, Germany	Civil Society	20	Germany
14	Other	UNIOL	German Unification Day	October, 3rd, 2014	Hannover, Germany	Civil Society	500,000	Germany
15	Presentation	CSIC	Musical Tentacle	September 25, 2015	Barcelona, Spain	General public	100	Spain
16	Presentations	UNIOL	Meerestechnisches-Kolloquium	December, 8th, 2014	Wilhelmshaven, Germany	Scientific Community	10	Germany
17	Conference	& UNIOL	ASLO	February, 23rd – 27th 2015	Granada, Spain	Scientific Community		International
18	Workshop	CSIC & UNIOL	Sea-kayak workshop	April, 1st 2015	Llançà, Spain	Civil Society	30	Germany, Spain
19	Other, Press release, & popular press	& UNIOL	Blue Info Days	April, 25th – 26th 2015	Wexford, Ireland	Scientific Community, Civil Society, Policy Makers, Medias	-	Europe
20	Conference	UNIOL	Citizens observatories: empowering societies	December, 4th, 2014	Brussels	Scientific Community	-	International
21	Presentations	UNIOL	POLMAR Graduate School colloquium	February 10th, 2015	Bremerhaven, Germany	Scientific Community	20	Germany, International
22	Other	UNIOL	Ocean Sampling Day	June 21, 2015	Wilhelmshaven, Germany	Scientific Community, Civil Society	200	International
23	Other	UNIOL	Ocean Sampling Day	June 21, 2014	Wilhelmshaven, Germany	Scientific Community, Civil Society	15	Germany

24	Conference	UNIOL	Citizens between engagement and science- Citizen Science: perspectives, challenges and constraints"	January 26 – 27, 2015	Osnabrück, Germany	Scientific Community, Civil Society, Policy Makers	>100	Germany
25	Workshop	UNIOL	Sparkling Science Workshop	December 15, 2014	Wien, Austria	Scientific Community	-	Germany, Austria
26	Other	UNIOL	High Seas High School	October 2014-- May 2015	Witbülten, Germany (crossing Atlantic ocean to Caribbean, Panama & Cuba.	Scientific Community	20	Germany
27	Workshop	UNIOL	Senior Academy	June 19 – 20, 2014	Wilhelmsha ven, Germany	Civil Society	20	Germany
28	Other	UNIOL	Exhibit	March 2014 ongoing	Wilhelmsha ven, Germany	Civil Society	(in permanent exhibition)	Germany
29	Other	UNIOL	Exhibit	21 March 2015 ongoing	Wittbülten, Germany	Civil Society	(in permanent exhibition)	Germany
30	Other	& UNIOL	Grevelingen	August 29, 2013	Lake Grevelingen , NL	Civil Society	15	Netherlands
31	Thesis	UNIOL	Entwicklung einer Mehrkanal-Fluoreszenz-Ansteuerung für smartphonebasierte Umweltüberwachun g	October 2015	Wilhelmsha ven, Germany	Scientific Community	-	Germany
32	Presentation	UNIOL	Potentials of the Citclops-app. Mapping out a possible success on the basis of ferry lines in the North Sea	March, 2014	Wilhelmsha ven, Germany	Scientific Community	20	Germany

2.2. Section B

Section B (Confidential[8] or public: confidential information to be marked clearly)

Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

Table 5 LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[9]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)

[8] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.
[9] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Three business cases have been identified for the exploitation of foreground:

1. **Monitoring projects**, driven by the information requirements of **researchers** (citizen science) and **decision makers** (participatory monitoring); funded by government agencies in relation to the improvement of environmental policies.

2. **Communication/outreach platform**, for educational/lobbying use by a (regionally-focused) organisation or group of citizens interested in reporting and sharing water-quality data; funded by advertisement, or by the user group, or by subscription contributions.

3. **AI-based monitoring technologies**, providing private companies with **advanced water information** or with **water-quality measuring** capabilities; funded by private companies.

Monitoring projects

This business case involves the exploitation of software **tools to collect observations of the environment following a citizen-science methodology** (foreground) and is summarised in Figure 27, composed of the typical nine blocks of business-model canvases and addressing the main factors characterising the sustainability of the business case. Within this model, the right-hand side represent the external factors, the left-hand side deals what concerns the internal organisation of the service. The **value proposition** refers to a customer represented by a public body, either a centre conducting research in the coastal or inland-water environment, or a body in charge of reporting on the assessment of water quality under the constraints of national, European or international regulations:

1. A **research centre** would be able to collect citizen-science observations of the aquatic environment from Citclops tools, to complement more traditional data-sources and observation-networks such as traditional in-situ measurements, samples analysed in laboratories, numerical modelling, satellite-derived products, precise but sparse observation stations like instrument towers or buoys measuring water optical-properties with hyperspectral cameras.

2. A **watershed agency**, a **governmental institution**, or a **natural-park--managing** organisation, in charge of providing a regular reporting to competent authorities on water quality in order to comply with European or international commitments regarding the preservation of the environment, for instance the Water Framework Directive, the Marine Strategy Framework Directive, the Bathing Water Directive or the OSPAR convention, would be able to collect additional, citizen-science observations of the aquatic environment from Citclops tools.

3. An **NGO**, whose aim is to raise the public awareness of coastal environmental issues, and to influence environmental policies, could use Citclops monitoring tools to provide evidence of concerns/risks about water quality, possibly not recorded by official monitoring systems, for instance because monitoring based on official protocols is not frequent or spatially-dense enough to detect very local or temporary events like (potentially harmful) algal blooms, or because it does not take into account indices of pollution like the presence of plastic trash on beaches.

Key Partners

- Citclops partners
- Other industry & RD institutions that bring related, complementary inexpensive sensors and apps to the market
- Citizens: providers of crowdsourced data
- Public/regional agencies committed to provide reporting on water quality
- GEOSS, Copernicus, EMODnet: provider of satellite and other data

Key Activities

- Maintenance and evolution of the Citclops DSS technology (web, app)
- Keep interaction with Citizen
- Creation of new application zones according to end-users needs
- Regular updates with data (crowdsourced, inexpensive sensors, satellite)
- R&D to improve the DSS performance and scope (sensors, processing, prediction, new parameters)

Key Resources

- The Citclops DSS and app
- Data: crowdsourced, sensors, satellite
- IPR : algorithms, new sensors design
- Computer hardware: host servers & community fora

Value Propositions

- More information available through data participatory science & monitoring and inexpensive sensors
- Support the decision-making process of end-users for day-to-day activities, or for policy
- Maximise the end-user experience: user-friendly interfaces
- Social networking to connect citizen, policy makers and researchers to each other
- Prediction of water bio-optical properties in support of water quality monitoring
- Validation of the information provided through scientific protocols

Customer Relationships

- Access to observations
- Access to indicators for decision taking
- Access to Citizen discussions on social media.

Channels

- The Citclops DSS interface (web, app)
- Citclops Social media

Customer Segments

- Governmental water management agencies
- Natural parks
- Research institution, laboratory
- NGOs

Cost Structure

- Personnel costs for maintenance, evolution of the DSS
- Personnel cost for social media moderation
- Personnel cost for R&D
- Selling, administrative expenses
- Infrastructure costs : Citclops server(s), maintenance, archiving

Revenue Streams

- Governmental agencies (customer : governmental agencies)
- Public research funding (customer : researchers)

Figure 27. "Monitoring projects" business case

Communication/outreach platform

This business case involves the exploitation of **sensors to collect observations of the environment following a citizen-science methodology** (foreground) and **associated information-delivery services** in communication/outreach platforms, and is summarised in Figure 28. The **value proposition** refers to a customer represented by individuals belonging to an association and involved in activities in connection with the environment and/or with the use/development of simple sensing devices, or teachers of a school. Examples of such associations, which typically are local, and regularly realise their activities at specific spots are:

1. **Clubs/associations for nature observation** (general)

2. **Clubs/associations proposing environmental observation activities**, oriented to DIY technology and working on electronic devices

3. **Sporting clubs/associations** devoted to water–related activities, such as yachting, kayaking, diving and recreational fishing

In the case of **teachers**, they could illustrate how single observations of the environment (e.g., optical water-data as proxies of water quality) can be integrated into larger systems that allow to aggregate many individual observations made by pupils, and provide a more complete picture of the environment on a certain location during a certain period.

Key Partners	Key Activities / Key Resources	Value Propositions	Customer Relationships / Channels	Customer Segments
• Citclops partners • Other industry & RD institutions that bring related, complementary inexpensive sensors and apps to the market • Citizens: providers of crowdsourced data • Public/regional agencies committed to provide reporting on water quality • GEOSS, Copernicus, EMODnet: provider of satellite and other data	**Key Activities** • **Maintenance and evolution** of the Citclops DSS technology (web, app) • Keep interaction with Citizen • Creation of **new application zones** according to end-users needs • Regular **updates with data** (crowdsourced, inexpensive sensors, satellite) • R&D to **improve the DSS performance and scope** (sensors, processing, prediction, new parameters) **Key Resources** • **The Citclops DSS and app** • **Data**: crowdsourced, sensors, satellite • **IPR** : algorithms, new sensors design • **Computer hardware**: host servers & community fora	• **Participate to the collect of environmental observation** • Share of the information with other individuals with the motivation of common interest • Maximise the **end-user experience**: user-friendly interfaces • **Social networking** to connect individuals, and provide a form of social recognition • **Prediction** of water bio-optical properties in support of water-related activities	**Customer Relationships** • Access to observations • Access to Citizen discussions on social media • Form of social recognition **Channels** • The Citclops DSS interface (web, app) • Citclops Social media	• Teachers • Sporting clubs • Clubs of electronics • Clubs for nature observation

Cost Structure	Revenue Streams
• Personnel costs for maintenance, evolution of the DSS • Personnel cost for social media moderation • Personnel cost for R&D • Selling, administrative expenses • Infrastructure costs : Citclops server(s), maintenance, archiving	• Internet advertisement : Pay-Per-Click, Cost-Per-Mille, Cost Per Acquisition • Partnership with stores.

Figure 28. "Communication/outreach platform" business case

Customers, in this business case, are interested in obtaining environmental information relevant for their activities, in particular in relation with water transparency. Individuals belonging to these groups are also inclined to share their information with others, and the use of mobile apps and social media makes the information-delivery services attractive to them. These individuals can be at the same time the customer of the sensor/service, and the data provider.

AI-based monitoring technologies

This business case involves the exploitation of **AI-based monitoring technologies** (foreground) and can be implemented into several variants depending on the particular technology exploited, and on which customer is targeted. As examples, two potential scenarios are illustrated concerning the **industry** sector:

1. The **dredging sector**. During dredging operations, depending on the location, certain regulations force to measure the *total suspended matter* (TSM) concentration by regularly analysing water samples in the turbid plume and to stop the dredging operation if the TSM exceeds a threshold, in order to avoid possible damage to the environment, like silt deposit over benthic flora and fauna. Such interruptions are necessary and beneficial, but lead to increased cost. Often, excessive TSM is the result of non-optimal dredging, which in turn can be the result of non-optimal monitoring. To improve the situation, several KdUINO buoys could be used, equipped with data transmission systems, reporting in real-time information on light attenuation in the water column at strategic locations around the dredging area. Such frequently refreshed information, together with AI-based monitoring techniques able to predict future TSM levels, would help the operation team to adjust the intensity and/or other parameters of the dredging operations so as to avoid reaching unacceptable turbidity levels and being forced to interrupt the work. Dredging operators may be interested in a pilot test, and possibly to adopt this AI-based monitoring technologies as a complement to existing protocols imposed by the regulations. The value proposition for the customer is therefore: optimising its dredging operation by limiting stand-by periods, and hence reducing its costs.

   An **instrument company**. A license could be granted for the production of KdUINO buoys to a company specialised in assembling instruments for the monitoring of the water environment in an cost-effective way, thus providing potential revenues to the company building the device. If the KdUINOs are used in the industry sector, for example in dredging operations as the ones described in the previous scenario, then this could provide revenues also to an organisation (likely a Citclops partner) providing assistance to the (dredging) company in the use of the KdUINO.

Table 6 List of exploitable foreground

Type of Exploitable Foreground [10]	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[11]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Software	*Ocean Colour satellite image processing chain*	*yes*	*2025*	*N/A*	*Environment (coastal, inland waters), aquaculture*	*2015 2025*	*N/A*	*Beneficiary NOVELTIS (owner)*

[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.

[11] 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[10]	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[11]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Data	*Ocean colour*	*no*	*N/A*	*Maps of water quality indicators on the Wadden Sea (North Sea) and Alfacs bay (Mediterranean).*	*Environment (coastal, inland waters), aquaculture*	*2015 2025*	*N/A*	*All partners (data delivered to the European Commission)*
Software	*Quality checking of Forel-Ule in-situ observations*	*yes*	*2025*		*Environment (coastal, inland waters), aquaculture*	*2015 2025*	*N/A*	*All partners*
General advancement of knowledge	*Tools to collect observations of the environment following a citizen-science methodology*	*no*	*N/A*	*Monitoring solution*	*M72 - Scientific research and development*	*2015*	*N/A*	*Free software and tools*
General advancement of knowledge	*Sensors to collect observations of the environment following a citizen-science methodology*	*no*	*N/A*	*Communication/ outreach platform*	*M72 - Scientific research and development*	*2015*	*N/A*	*Free software and tools*
General advancement of knowledge	*KdUINO, AI techniques*	*no*	*N/A*	*AI-based monitoring technologies*	*M72 - Scientific research and development*	*2015*	*N/A*	*Free software and tools*

3. Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*

Grant Agreement Number:	308469
Title of Project:	Developing community-based environmental monitoring and information systems using innovative and novel earth observation applications (Citclops)
Name and Title of Coordinator:	Luigi Ceccaroni

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) :	
RESEARCH ON HUMANS	
• Did the project involve children?	YES
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	YES
• 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?	YES
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)?	YES
DUAL USE	
• Research having direct military use	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		1
Work package leaders	1	6
Experienced researchers (i.e. PhD holders)	4	9
PhD Students	2	1
Other	7	3

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**0**
Of which, indicate the number of men:	

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	● ●	Yes (UNIOL)

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 (UNIOL: Not specifically, but by inviting a cross section of the public)

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
TCD/Coastwatch: in wide range of settings from classroom, teacher in-service training events to festivals including the national ploughing championship for coastal farmers and urban festivals like Dublin Rose Festival and kite festivals. Dedicated events included Blue Info-days and Open House event organised in Co Wexford. Joint work with the national Life guard association and Ireland's sail training vessel The Spirit of Oysterhaven.
UNIOL: Working with school pupils and students during dedicated training events
MARIS: Open house events in Wexford and Wilhelmshaven: involvement of students, school kids, junior rangers
CSIC: KdUINO development kit. Web (in Spanish) to explain how to build your own KdUINO.

○ No

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

● Yes- please specify:
NIOZ: Forel-Ule scale toolkit manufactured by Atelier VIX Amsterdam (http://forel-ule-scale.com/), a website www.eyeonwater.org, an instruction video **Seas of colour** (see https://youtu.be/JPfJsMA813E), a smartphone application named **EyeOnWater**, to determine the colour of natural waters post Citclops, available at Google Play and Apple Store.
UNIOL: Exhibits in environmental visitor centres, informational text on website, do-it-yourself explanation for Citclops techniques, videos.

○ No

F Interdisciplinarity

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

- ○ Main discipline[12]: 1.4; 1.1; 1.4; 1.5; 5.3
- ○ Associated discipline¡Error! Marcador no definido.: 1.2 | ○ Associated discipline¡Error! Marcador no definido.:

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?

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

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

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?	**11**
To how many of these is open access[13] provided?	**5**
How many of these are published in open access journals?	**3**
How many of these are published in open repositories?	**3 (research gate)**
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[14]: ……………	
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	
	Registered design	
	Other	

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:	

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 **(VU-VUmc)**	❑ 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:* *1* For Deltares: as Citclops spinoff we may be able to

[13] Open Access is defined as free of charge access for anyone via Internet.
[14] For instance: classification for security project.

Difficult to estimate / not possible to quantify	generate new work (otherwise not generated) for prolonged time for various people across the organisation equivalent of 1 FTE ❑

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]

4. List of Key Words/ Abbreviations

CDI	Common Data Index
CLAHE	contrast limited adaptive histogram equalization
CO	citizen observatory
DIY	do-it-yourself
ISO	International Organization for Standardization
KBS	knowledge-based system
OGC	Open Geospatial Consortium
QC	quality control
RGB	red-green-blue
SOS	sensor observation service
TSM	total suspended matter