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WATeRS: A Web Map Service with near-real time MODIS standard chlorophyll products of the North Sea

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Abstract

WATeRS, a portal for water quality information products from operational remote sensing http://ivm10.ivm.vu.nl/mapserver/WATeRS serves near-real time satellite derived water quality information open and interactively available for all on the Internet. It is based on automated conversion of satellite data (in scientific formats) to GIS formats, and comprises a customised ArcIMS-application with a WMS ArcIMS-OGC connector. It enables users to interactively explore remote sensing products, and to seamlessly combine this data with other data with a geographic component. The robust service has been used for automated data collection since Jan 2005, has a growing user group, and should be embedded into a larger framework to ensure continuity of the near-real time service.

Key words: Ocean Colour, Remote Sensing, Water Quality Products, Phytoplankton, Patterns, Web Map Server, Metadata, http://ivm10.ivm.vu.nl/mapserver/waters

1. Introduction

Phytoplankton concentrations can be derived with remote sensing (or earth observation) techniques because of the spectral characteristics of the chlorophyll (CHL) pigment. The MOderate Resolution Imaging Spectroradiometer (MODIS) is a 36-band spectrometer observing the land, atmosphere, and oceans within a wavelength range of 412 to 14 385 nm (Esaias et al., 1998). Chlorophyll data from MODIS Aqua Level-2 Local Area Coverage (LAC) data products are brokered in compressed scientific data format from NASA's Ocean Biology Processing Group (Feldman and McClain, 2006). Standard MODIS Aqua Level-2 chlorophyll (CHL) concentrations are calculated with the MODIS Chlor_a_3 semi-analytical algorithm (Equation 1) that uses the spectral absorption properties of phytoplankton in the surface waters to derive the concentration of chlorophyll-a (O'Reilly et al., 2000).

$$CHL = 10.0^{(0.2830 - 2.753 R_{3M} + 1.457 R_{3M}^2 + 0.659 R_{3M}^3 - 1.403_{3M}^4)}$$
$$R_{3M} = \log 10(R_{550}^{443} > R_{550}^{490}) \qquad (1)$$

R_{3M} Equals the maximum reflectance (or satellite band) ratio.

Despite the application-orientated aims of remote sensing furthering the understanding of dynamics and processes (McClain et al., 2004), the usage is still principally limited to specialists. Notwithstanding attempts to make data and software openly available to all and additional outreach activities (McClain et al., 2004), we think this is, i.a., due to the format in which the datasets and derived products are available, the scientific software required to work with them, and the lack of context with which these datasets are offered.

In recent years, presentation of maps on the internet (Web mapping), has developed from static view-only pictures, to open interactive mapping incorporating (vector) GIS functionality (Plewe, 1997; Gittings, 1999; Kraak & Brown, 2001; Green & Bossomaier, 2002; Mitchell, 2005). The online display of information derived from remote sensing mainly focused on data dissemination and catalogue search functions (Eleveld et al.,1997). Nowadays, vector and image (raster) Web mapping are still developing independently, mainly because of the differences in data formats and underlying database structures (Gittings, 1999; Tsou, 2004). Semi-automated mapping of parameters derived from remote sensing and subsequently serving these as (georeferenced) pictures on the Internet is nowadays not uncommon for space agencies. In addition near-real time (NRT) satellite services have been set up using the X-band receiving systems capable of capturing direct broadcast data (Shutler et al., 2005). However, we think users might benefit from an even more elaborated end of the processing chain (Eleveld et al., 2003b): i.e. creating a NRT Web-mapping application that allows users to interact with the data derived from remote sensing.

Therefore, our objectives were to serve NRT satellite derived water quality information open and interactively available for all on the Internet, based on automated conversion of satellite data (in scientific formats) to GIS formats, and a customisation of an ArcIMS-application with a WMS ArcIMS-OGC connector. This should enable users to interactively explore the remote sensing products, and to seamlessly combine the data with other data with a geographic component. The open character should be compliant with the geodata infrastructures that are being developed (Nebert, 2004). Through the metadata, additional GIS layers and hyperlinks it should adhere to the request for context.

2. Method

We developed several programs to import, convert, project and subsequently serve remote sensing data in open GIS compliant format in a near-real time (NRT) web mapping application (Fig. 1).

2.1 Importing, converting and projecting remote sensing data

Running a program enables the data to be semi-automatically downloaded from an Ocean Color ftp site where NRT MODIS-Aqua data are staged in zipped hdf format. The same program geo-corrects un-flagged CHL data (to a geographic, lat-lon grid) using IVM's internal (Matlab) software library routines. A second program converts the resulting .mat files into ASCII grid files, and copies those to the server. The latest five are stored in a separate folder. An Arc Macro Language (AML) program contains instructions to project each of these files (to UTM zone 31N, WGS84), write the resulting ESRI GRID files to a folder with reprojected images, and move datasets older than 30 days to the WATeRS archive.

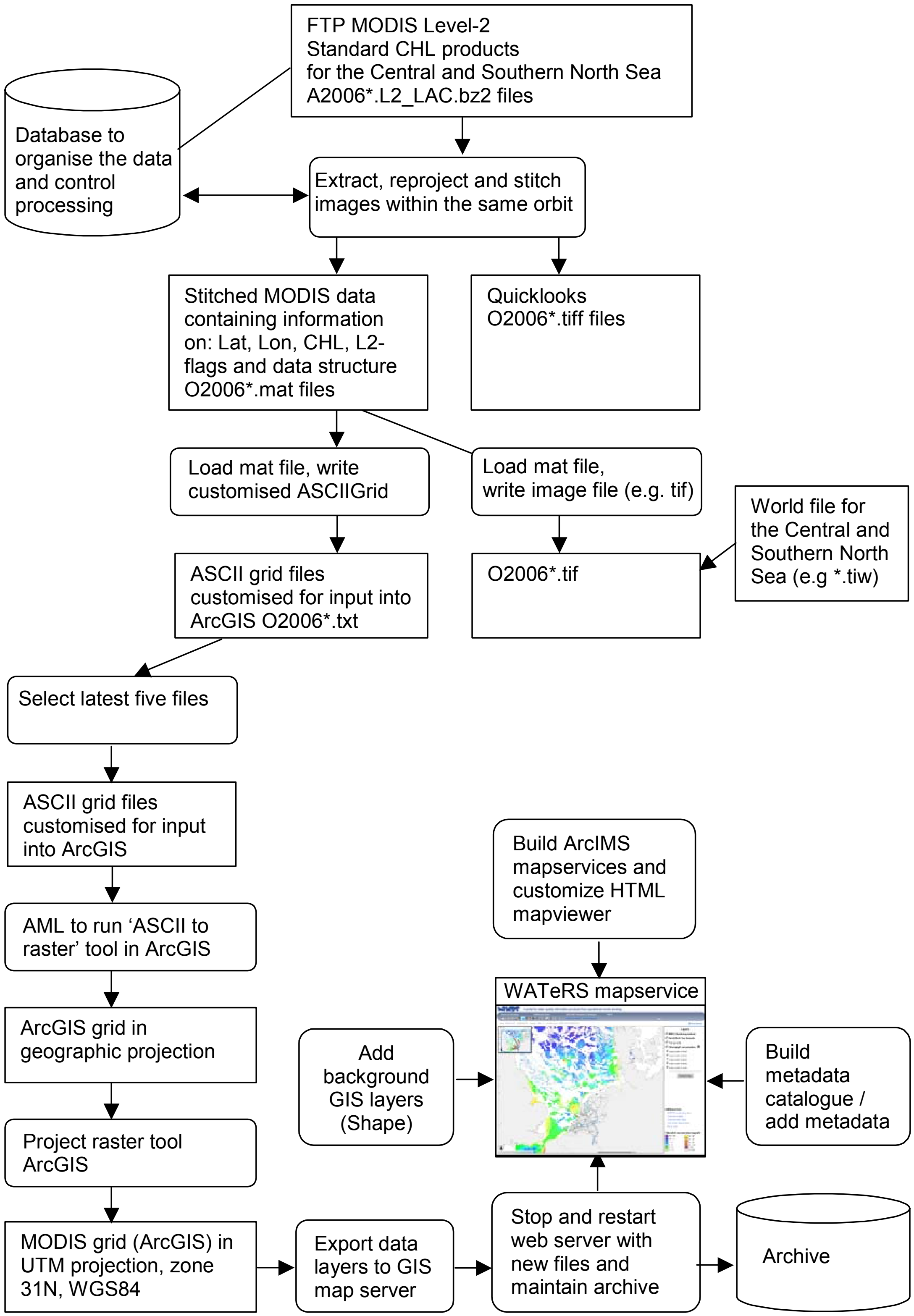


Figure 1: Processing flow.

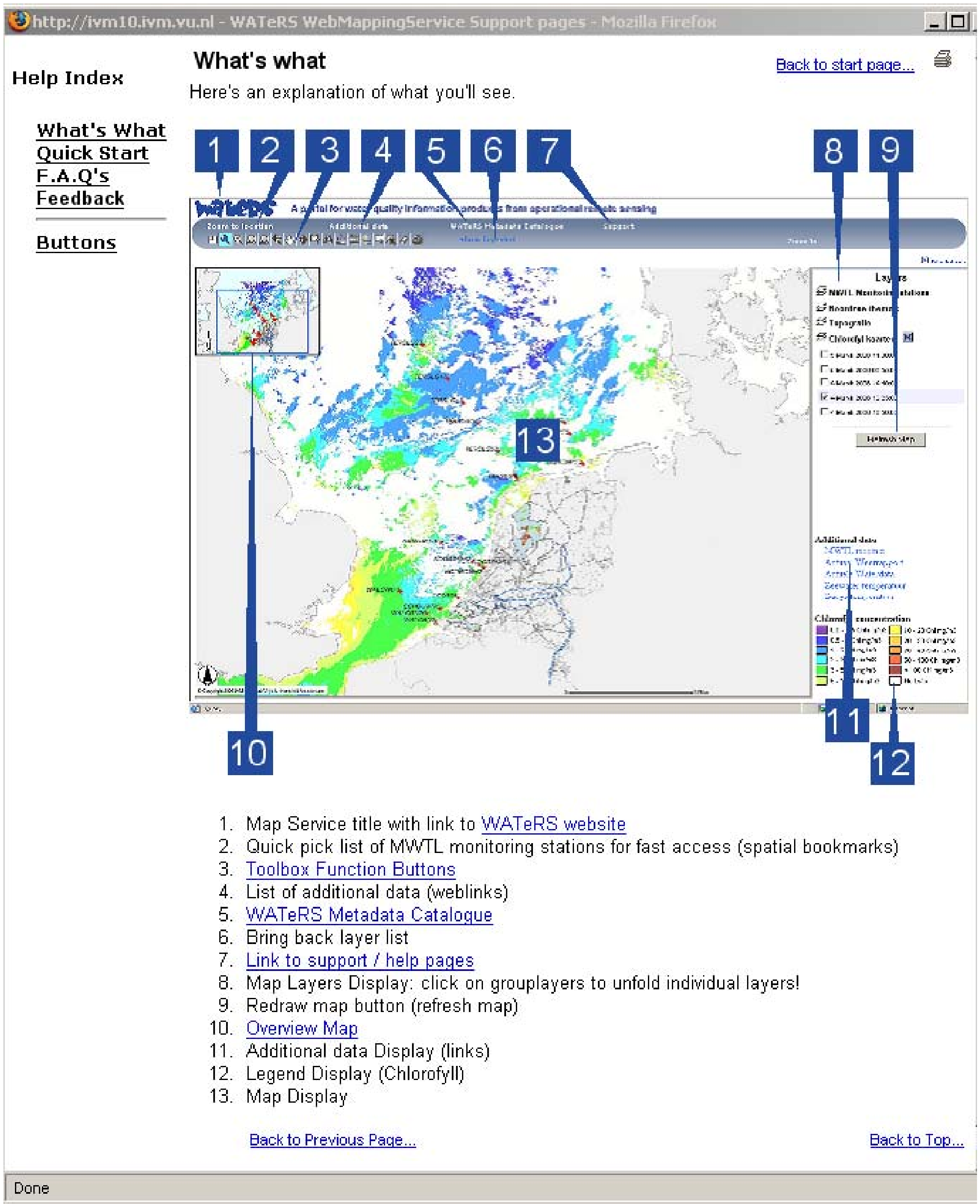


Figure 2: WATeRS GUI: layout, components and functionality (Source: WATeRS Help).

2.2 Serving water quality data for the North Sea

The WATeRS portal is based on standard technology, i.e. ArcIMS web mapping software, that complies with OCG and W3C standards. Mapservice configuration files to implement the mapservices in ArcIMS are AXL (Arc Extensible Markup Language, a specific type of XML) pages determining which and how the GIS layers are displayed including legends and classifications. We customised (Figure 2) standard ESRI ArcIMS image services (http://ivm10.ivm.vu.nl/mapserver/waters_defaultviewer, standard viewer).

For our aims we ***customised the ArcIMS application***, i.a.,by:

- Customisation of the standard ArcIMS HTML viewer of ESRI by altering the HTML and Javascript files that make up this mapservice
- Fig. 2 function number 2, spatial bookmarks monitoring stations (adapting ArcIMS building elements in JavaScript)
- Fig 2 nr 6 display of legends in a separate popup box stations (adapting ArcIMS building elements in JavaScript)
- CHL legend colour classification, MXD to *.AXL extension for ArcGIS (MXDtoAXL.zip, Jeroen Ticheler, http://arcscripts.esri.com)
- Fig 2 nr 8 layer management, the unfold mechanism for the group layers (adapted Grouptoc.zip, Bryan Baker, http://arcscripts.esri.com
- Identifying of Grid cells with the information button (RasterIDtools; 4.0.1 Widgets, Jeff Miller, http://arcscripts.esri.com).

Near-real time service updating implies to stop, restart, remove, add and refresh specific map services. That has been done remotely from a desktop PC by the use of a client program (PuTTY) that enabled control the ArcIMS services over our network by running a remote session on a computer (via SSH, Telnet and Rlogin network protocols).

Metadata, additional GIS layers and links to additional datasets for the North Sea ***offer integrated contextual information*** for the Remote sensing datasets. We developed the metadata catalogue http://ivm10.ivm.vu.nl/mapserver/waters/metadata/default.html with the purpose to provide users of the water quality portal with information regarding the assessment of meaning and value of datasets. Some characteristics of the metadata catalogue are:

- Conformation to the minimum set of mandatory metadata elements, CEN ENV 12657
- Understandable metadata elements: no codification but textual descriptions of map characteristics
- Flexible, but limited interoperability (simple Access database, but no direct exchange with other metadata catalogues or tools possible)
- Updateable anytime, anywhere (via the Internet)

Having the WMS ArcIMS-OCG connector installed, we ***created an open service*** simply by enabling the WMS connector for the WATeRS service.
To ***use*** it in an ArcGIS Desktop environment use for 'Add ArcIMS server' http://130.37.78.10 and select all services. For other software (e.g. MapInfo Professional 8.0) performing a GetCapabilities request and retrieving a map via the WMS ArcIMS-OGC connector, respectively, use the following links:

http://ivm10.ivm.vu.nl/wmsconnector/com.esri.wms.Esrimap/imageserver_waters2?request=getcapabilities&service=WMS&version=1.1.1

http://ivm10.ivm.vu.nl/wmsconnector/com.esri.wms.Esrimap?BBOX=-2.3254862073,50.3729074938,10.7386643238,58.1123008313&WIDTH=400&HEIGHT=300&SRS=EPSG:4326&Layers=Landen,Binnenwateren,Stedelijke%20gebieden%20Nederland,DEM,Bathymetrie,Rivieren%20Nederland,Rijkswegen%20Nederland,Zandwinning,Concessiegebieden,Baggerstortlocatie,Ankerplaats,Scheepvaart%20patroon,Continentaal%20plat,3%20mijls%20zone,12%20mijls%20zone,Boorplatforms,chloro5,chloro4,chloro3,chloro2,chloro1,Names%20monitoringstations,monitoringstations,&version=1.1.1&service=WMS&FORMAT=JPEG&TRANSPARENT=TRUE&request=getmap&ServiceName=imageserver_waters2

Different organisations currently provide spatial data products in specialized map services, and use partly overlapping datasets (IDON,2004). We investigated the application of the standard, interoperable, web mapping software of ESRI, the ArcIMS Multi-Service Viewer, which is one of the sample ArcIMS HTML viewers provided by ESRI. Using http://ivm10.ivm.vu.nl/mapserver/waters_multiservice/viewer.htm it is possible to combine services.

The service has been used for automated data collection since Jan 2005. Since the spring bloom period of 2005, publicity has been made for it. WATeRS has a growing user group (with on average 5 users per day (March - June 2006). An external company, Geodan IT, has ***tested*** the functionality and OpenGIS compliancy positively.

3. Results

The main result from a user point of view is the information service that enables users to interactively explore the remote sensing products, and to seamlessly combine the data with other data with a geographic component. On the long term this service might encourage the use of remote sensing RS (products) for, a.o., monitoring and planning purposes.

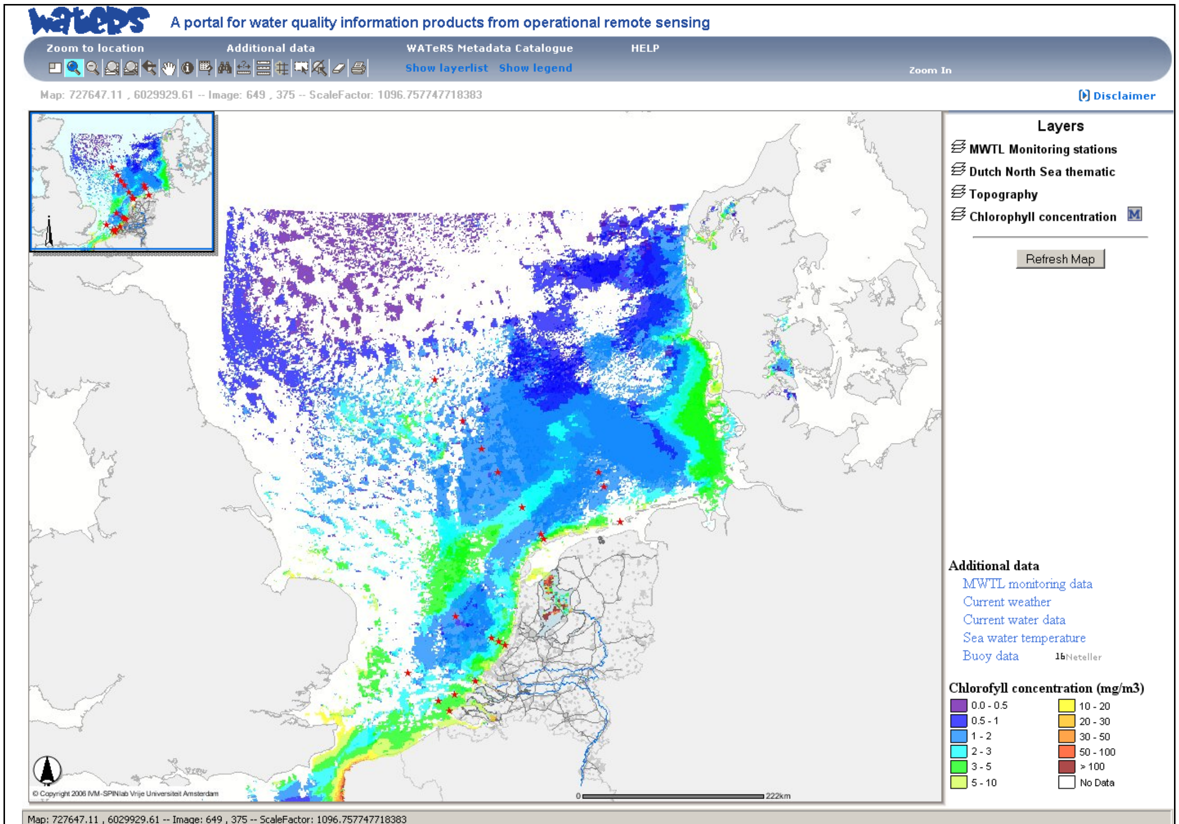
The main result from a technical point of view is the WATeRS portal itself, http://ivm10.ivm.vu.nl/mapserver/waters/, a novel customisation of an ArcIMS-application with a WMS ArcIMS-OGC connector having the following characteristics. The WATeRS portal:

(1) is a near-real time interactive, easily online accessible map service of water quality information from operational remote sensing, based on off the shelf technology that complies with open standards;
(2) serves verifiable results via a GIS based map service with a metadata catalogue that provides, amongst others, full lineage of the CHL maps;
(3) was customised to create a simple, clear and intuitive user interface, grid-cell query functionality, and automated archiving of produced map results.

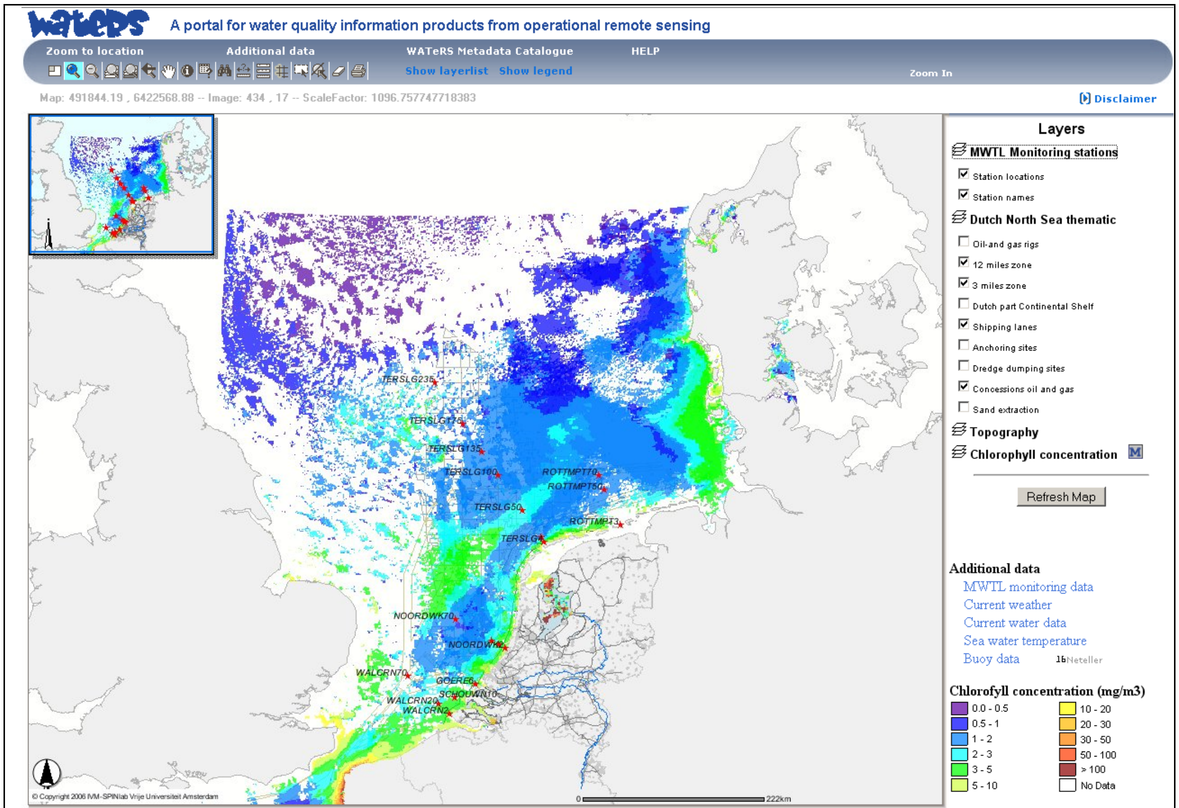
Using the portal would best illustrate this, but alternatively we present some examples in the form of storylines, which show the results, specific features, and illustrate possible interactions with WATeRS. Descriptions are given in the captions.

Storyline 1: From chlorophyll patterns to values and comparison with in situ measurements

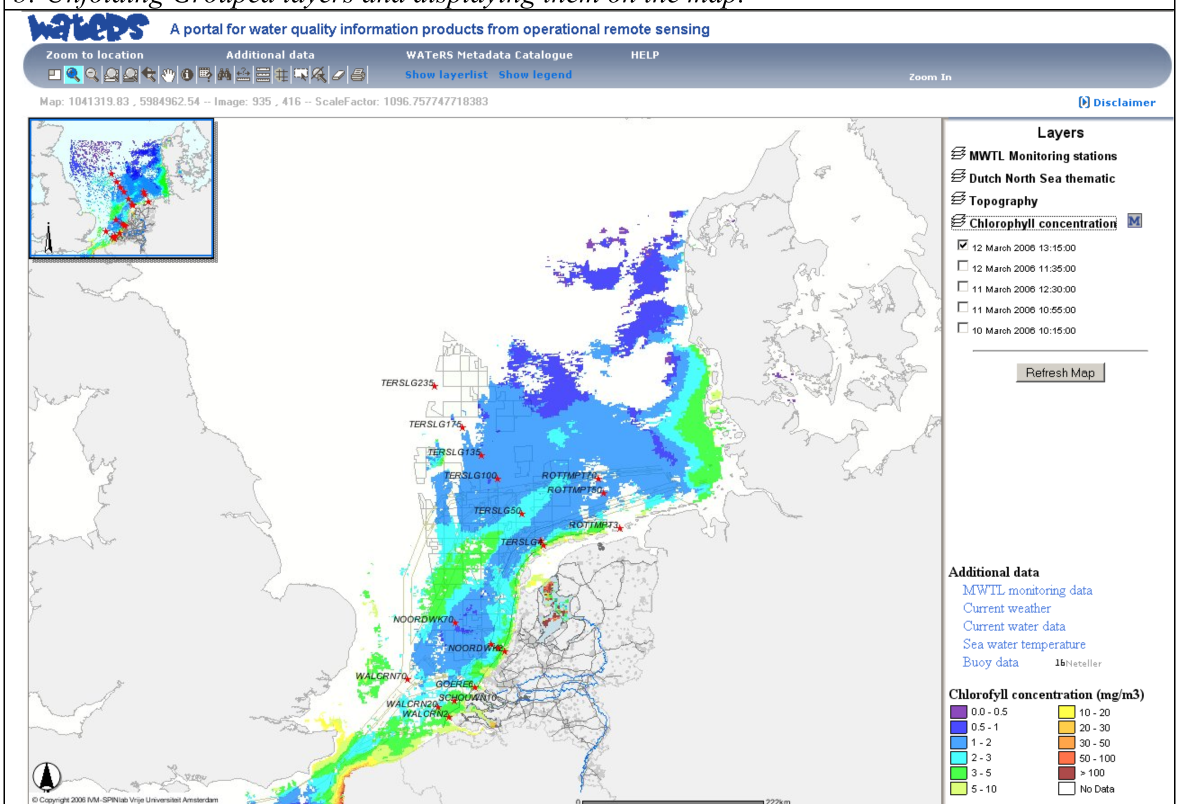
WATeRS is meant for exploration: the first storyline (Figure 3) shows how to get from an overview of CHL patterns to more quantitative information on CHL concentrations, and placing their value in a historical context. Demonstrated techniques include the interaction with ArcIMS and use of specific WATeRS tools, notably, unfolding folders (Figure 2 function number 8), using spatial bookmarks for zooming (Fig. 2 nr 2), retrieving the information on cell values, and using a hyperlink to additional data (Fig. 2 numbers 4 and 11).



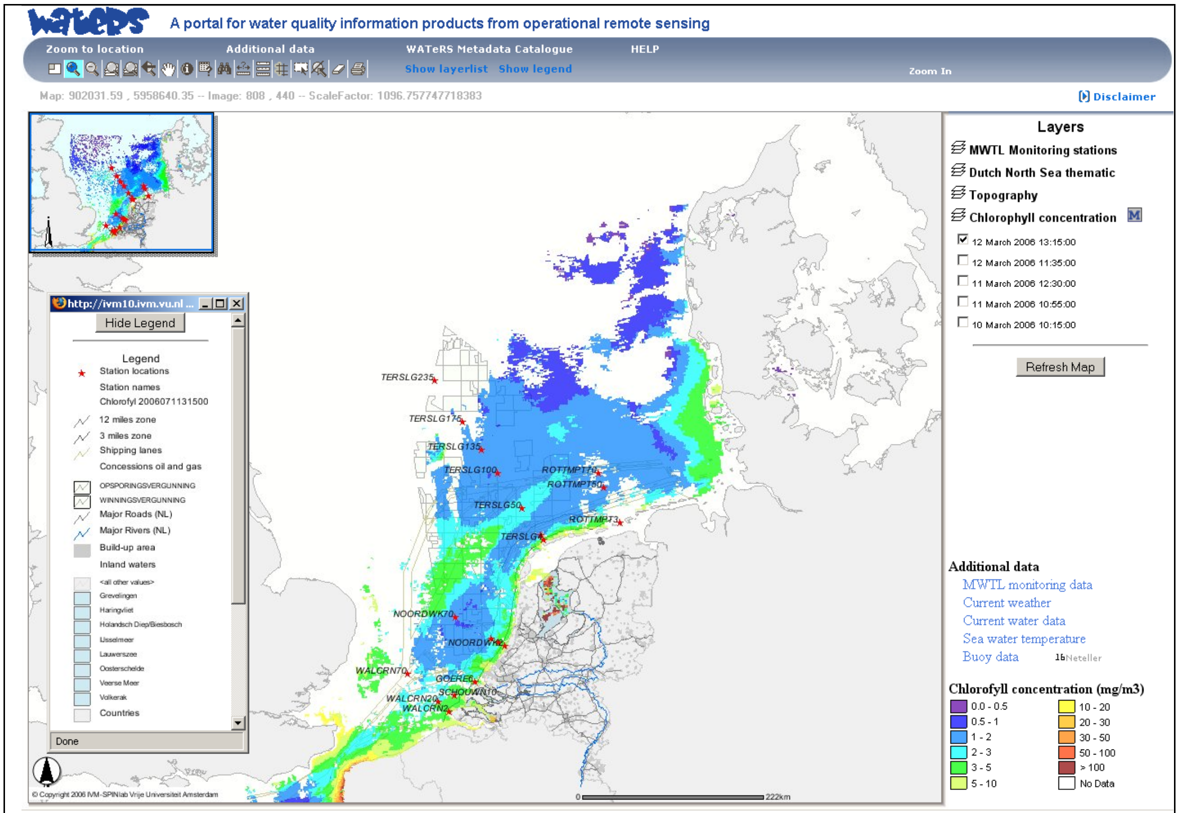
a: User interface WATeRS map service.



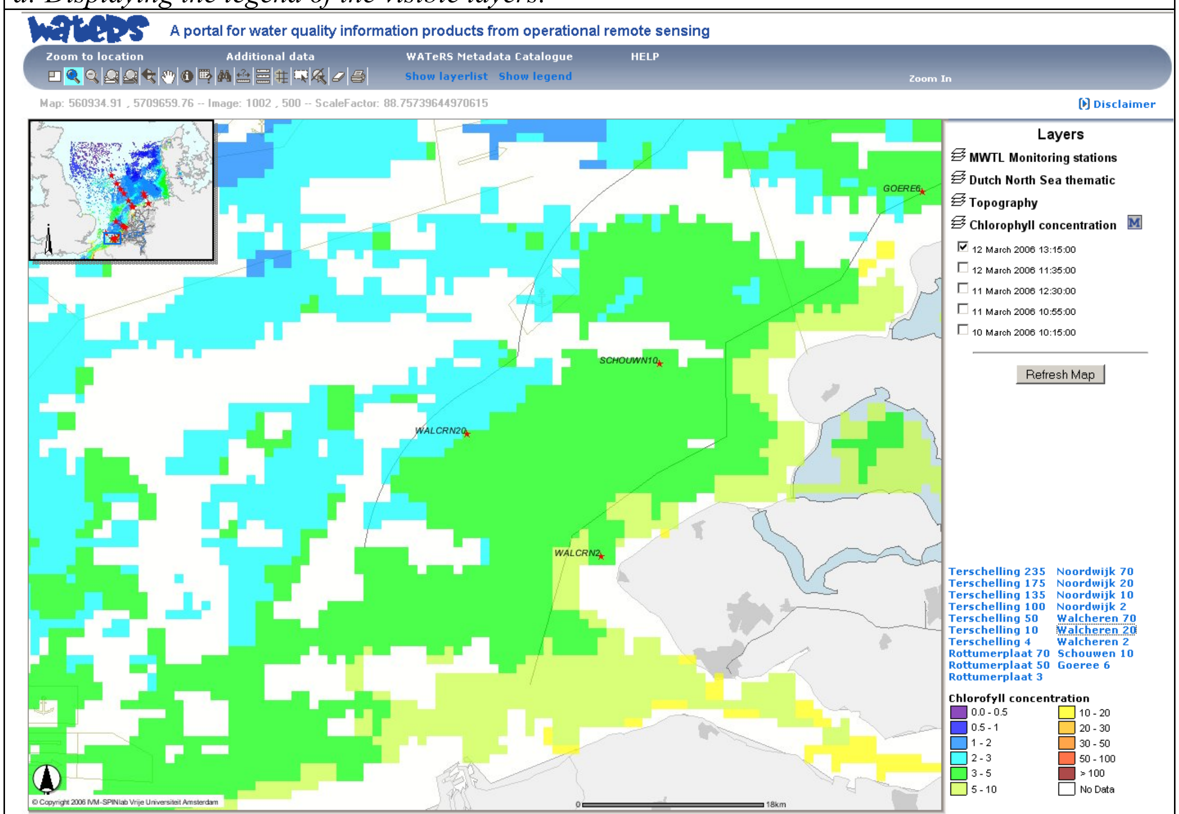
b: Unfolding Grouped layers and displaying them on the map.



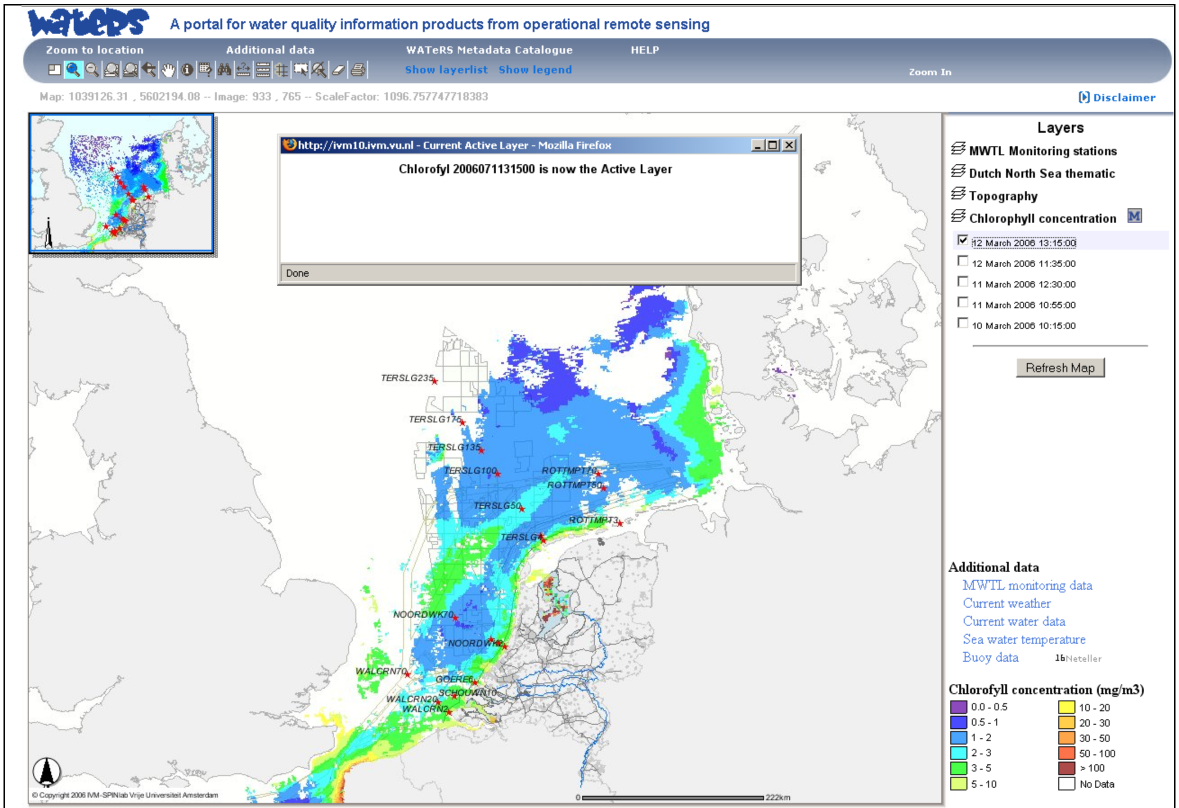
c: Displaying only one of the transparent chlorophyll raster layers.



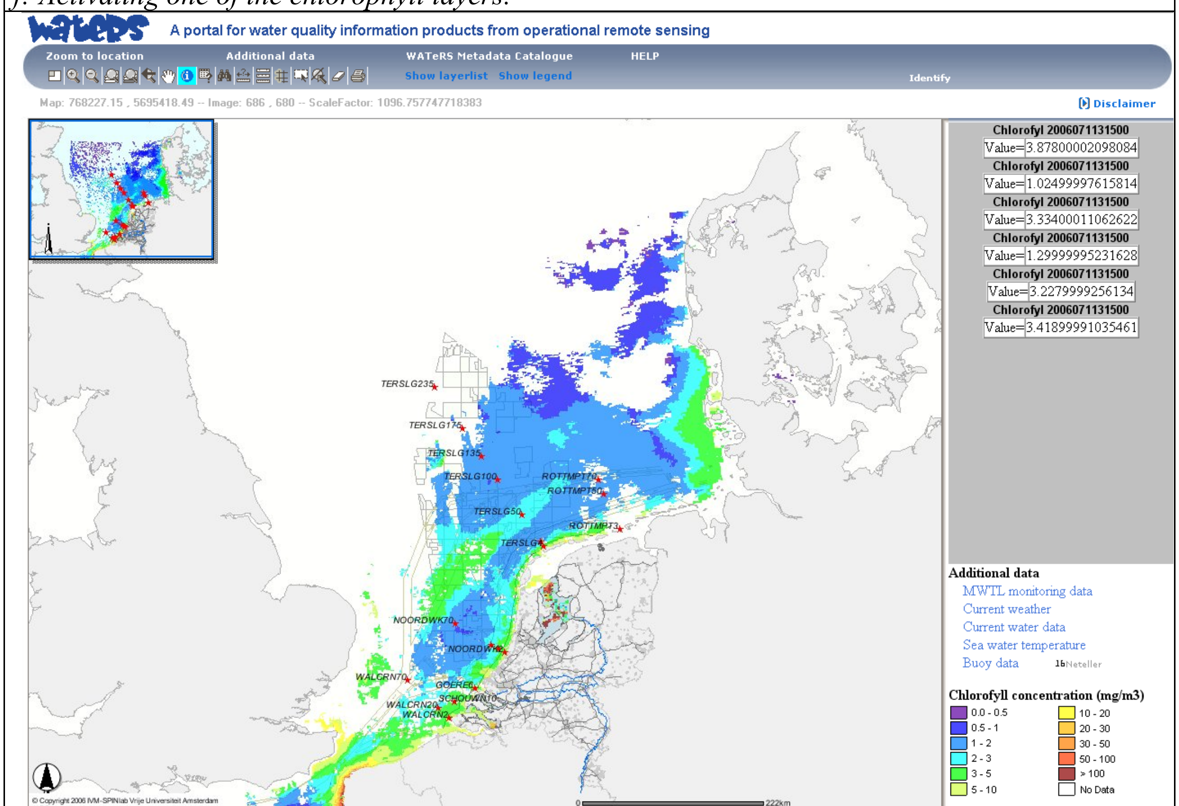
d: Displaying the legend of the visible layers.



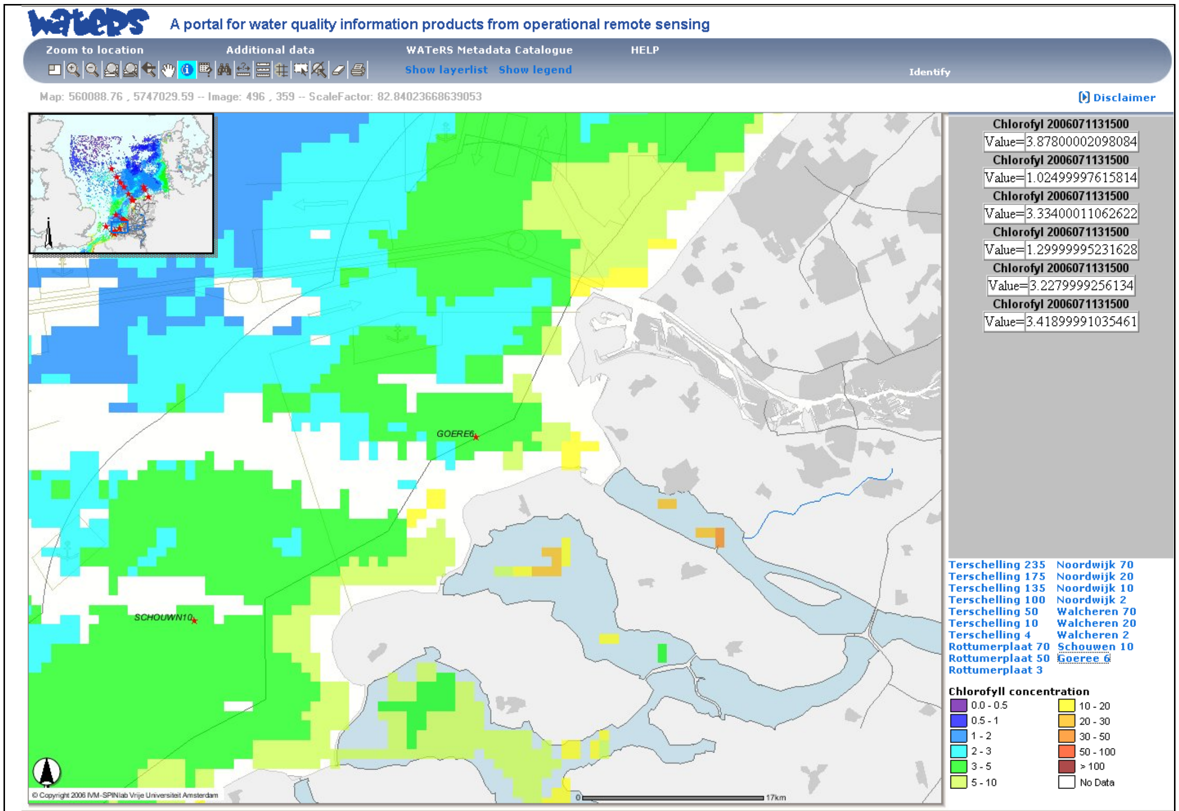
e: Using the spatial bookmarks for zooming to one of the MWTL (in situ monitoring) stations.



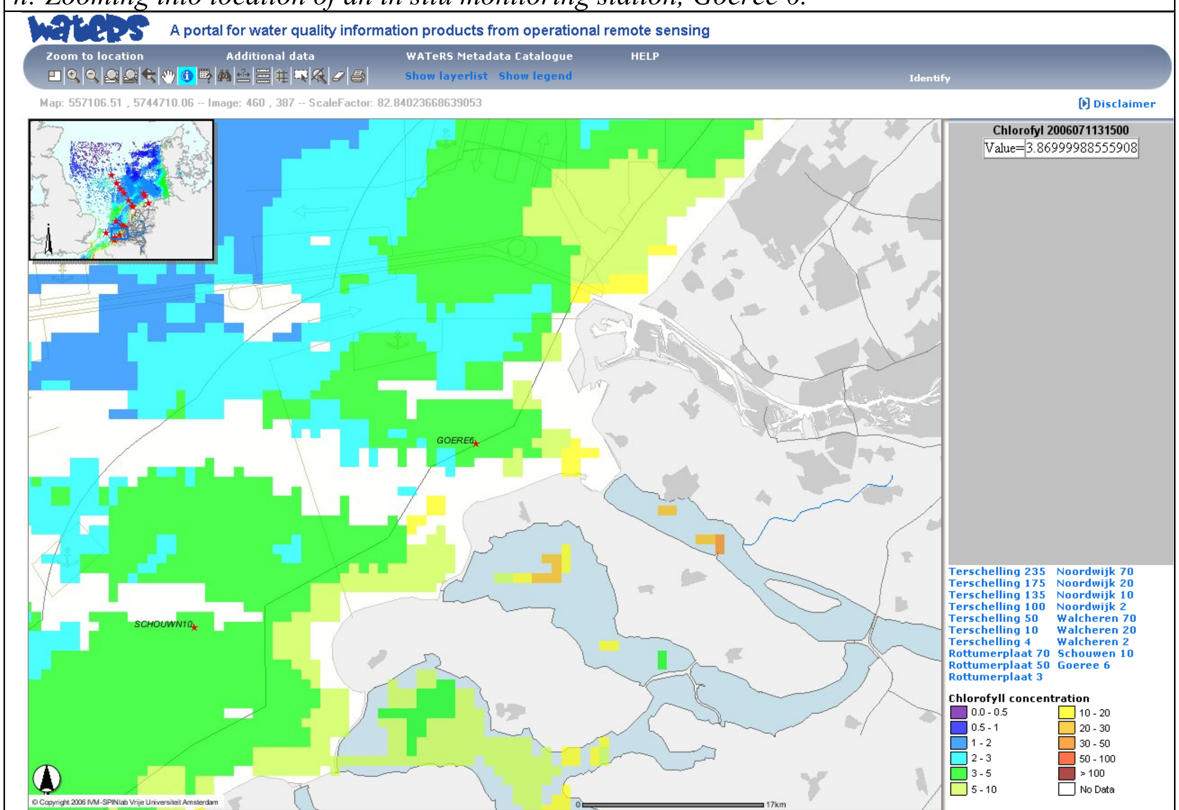
f: Activating one of the chlorophyll layers.



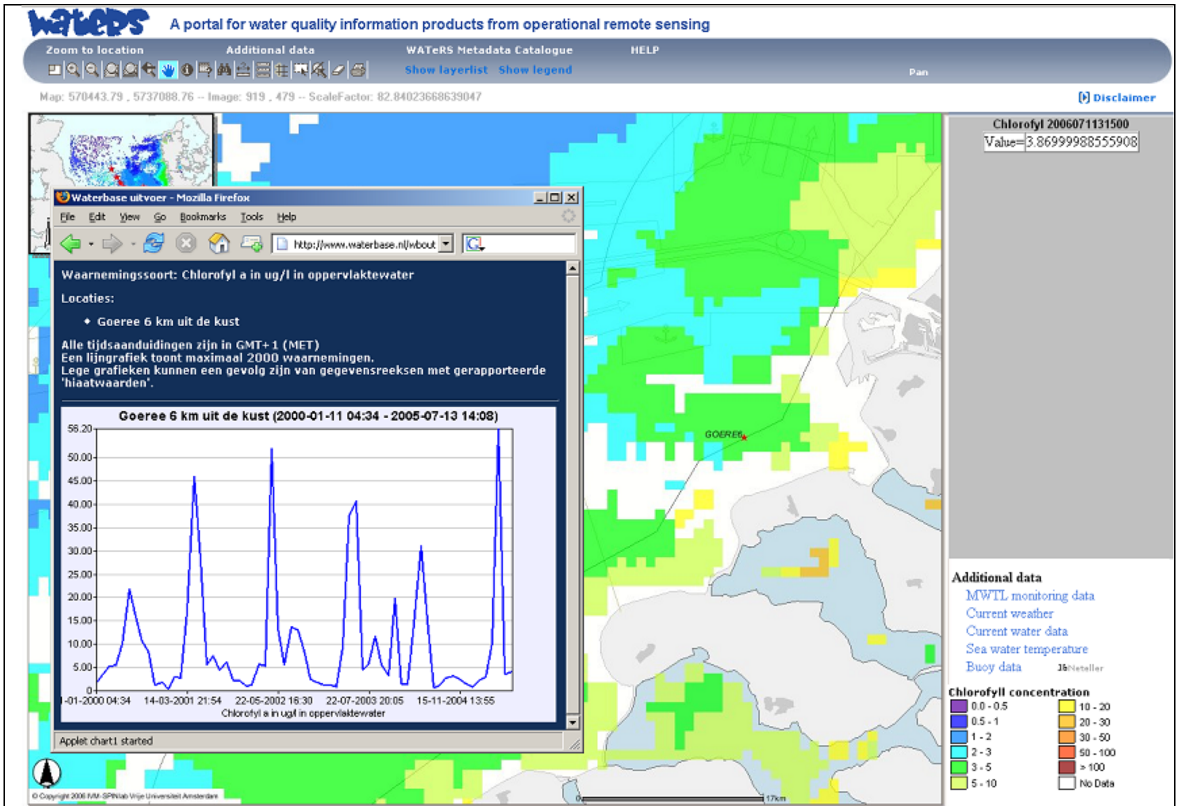
g: Retrieving individual raster cell values with the information button.



h: Zooming into location of an in situ monitoring station, Goeree 6.



i: Retrieving raster cell value on location of MWTL station Goeree 6.

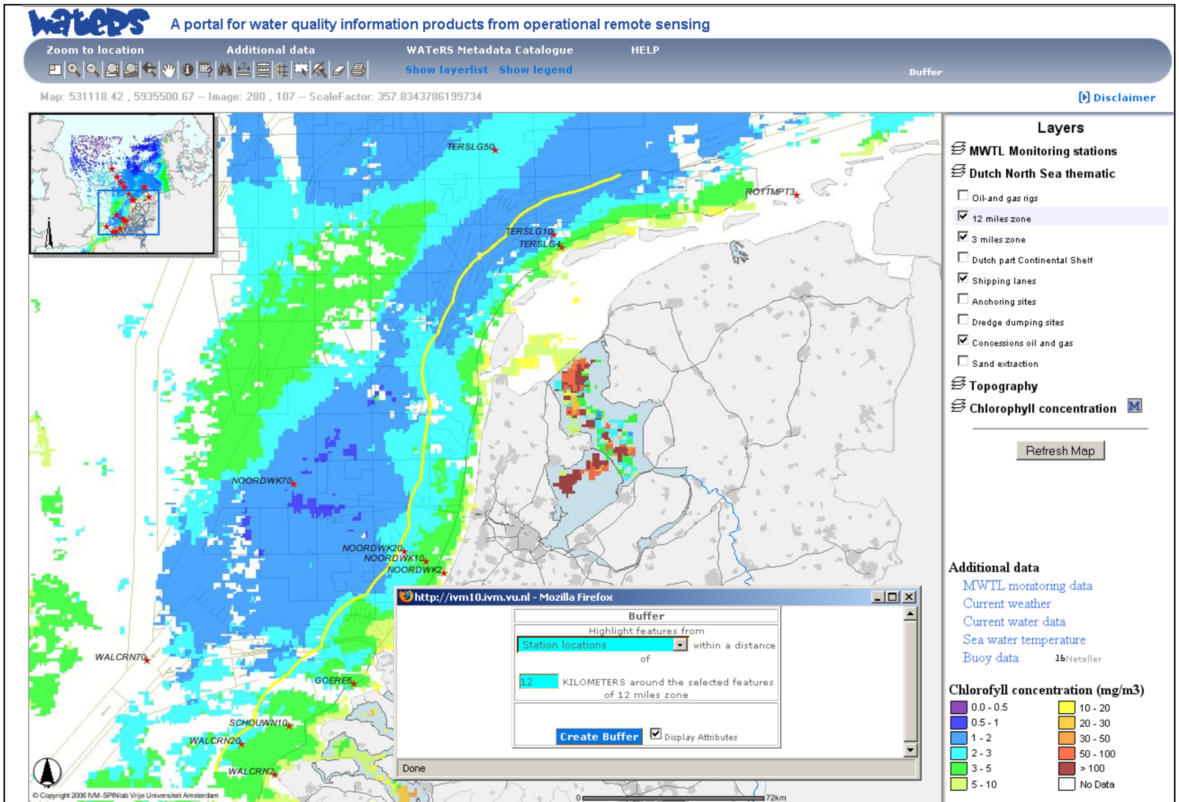


j: Comparing MWTL station Goeree 6 with additional in situ monitoring data (www.waterbase.nl) Available as a link in WATeRS under Additional data, MWTL monitoring data.

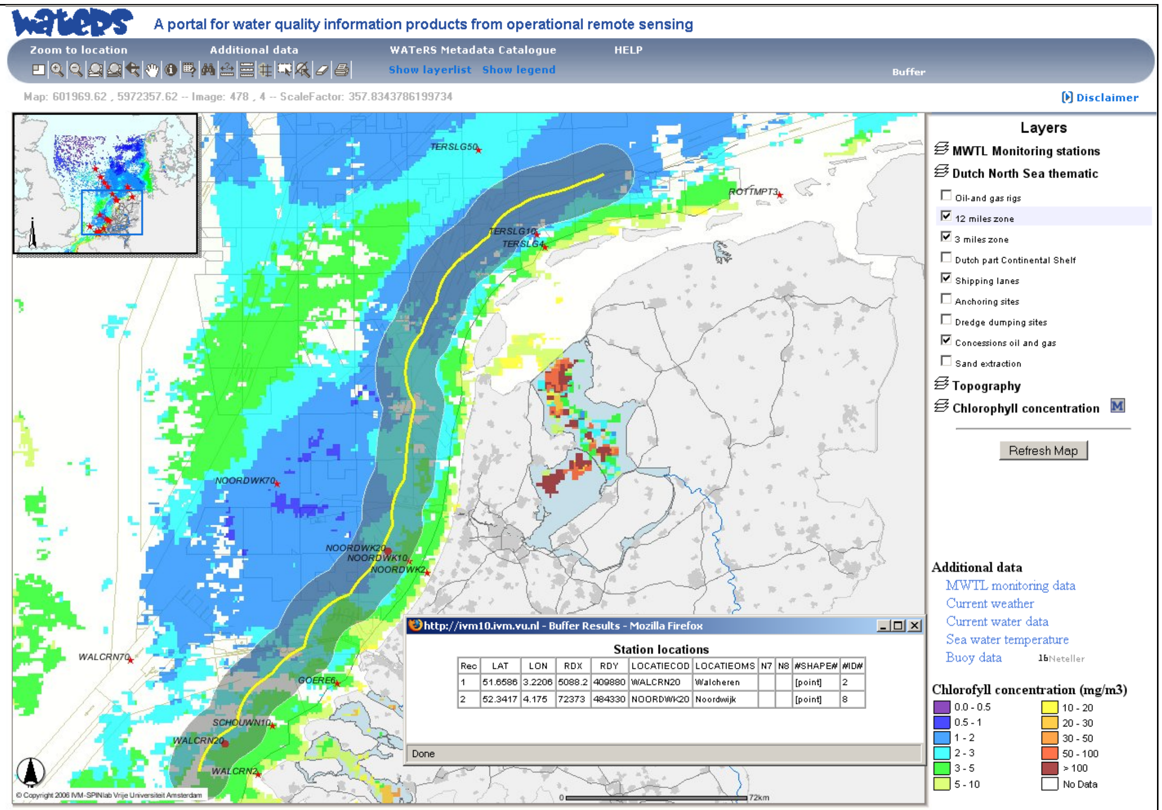
Figure 3 (a-j): Storyline from getting an overview of CHL patterns to more quantitative information on CHL concentrations, and placing their value in a historical context. Demonstrated techniques include general interaction with ArcIMS and use of specific WATeRS tools, notably, unfolding folders, using spatial bookmarks for zooming, retrieving the information on cell values, and using a hyperlink to additional data.

Storyline2: GIS analysis for management

WATeRS also enables simple vector GIS analyses within a coastal management context. Storyline 2 shows how to search for monitoring stations within a 12 km zone (buffer) around the 12 miles zone delineating Dutch territorial waters.



a: Selecting the 12 miles zone and creating a buffer.



b: MWTL stations falling inside buffer (12 km buffer around 12 miles zone).

Figure 4: Vector GIS analyses within a coastal management: searching for monitoring stations within a 12 km zone (buffer) around the 12 miles zone delineating Dutch territorial waters.

Discussion

Water quality parameters exhibit important spatio-temporal variability that can be well detected with remote sensing monitoring techniques. NRT serving of data derived from remote sensing in suitable (open) GIS or model formats might encourage further use for:

- Spatial planning at sea (designation of marine parks);
- Monitoring environmental quality: eutrophication assessments;
- Support to operational oceanography (NRT cruise planning);
- (Shell) fisheries;
- Input for modelling (data assimilation).

The WATeRS service has been created for MODIS L2 standard CHL products of the North Sea, but the procedure could easily be adapted for other parameters, algorithms and sensors, or other regions, as elaborated below:

- Using the MODIS L2 products to derive Sea Surface Temperature (SST) would require only minor modifications to the code, i.e. replace CHL by SST. Other MODIS of SeaWiFS products can also be simply be incorporated in the processing line.
- Likewise, water quality parameters (CHL, SPM, CDOM, K_D) that can be derived from satellite measurements of radiance with MERIS and IVM's own HYDROPT algorithm that was specifically developed to derive water quality parameters of North Sea Case 2 water masses (Pasterkamp et al., 2005), is also straightforward, because the WATeRS approach is generic: we solved the issues of handling file formats, and automated updating. (Because of the latter, application for other (e.g., land) applications should also be feasible.)
- Adaptation to a new region requires defining a new subscription ID for the MODIS ftp services, position in the Access database, and a new projection in the (AML) (Figure 1).

Particularly users of environmental and oceanographical data have multidisciplinary interests, and would like to combine different types of data of a certain geographic area (Eleveld et al 2003a). WATeRS allows integration and comparison of different datasets on different levels, and is targeted towards visualisation and grid query. For users also holding their own GIS data, we facilitate combination of distributed datasets in our map service (Section 2.2.). Nonetheless, we feel the developed and implemented services currently show only part of the application potential of both the remote sensing data, and the processing architecture behind this portal. Because of the limited scope of the project, more elaborate services such as those giving access to, and analytical usage of WATeRS's database with historical data are not yet fully exploited.

Conclusions

A number of developments made in this project can be used for other (water quality) parameters and sensors. The robust service has been used for automated data collection since Jan 2005, has a growing user group, is open. However, the project for the development of WATeRS is ending and WATeRS but should be embedded into a larger framework to ensure continuity in NRT updating, maintenance, and stimulate further developments.

Acknowledgements

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References

Eleveld MA, 1997. Optimizing the potentials of on-line satellite data servers for coastal research. Orlando, Florida Proceedings Fourth thematic conference on Remote Sensing for Marine and Coastal Environments. ERIM, Ann Arbour, 297-303.

Eleveld MA, Schrimpf WBH & Siegert AG, 2003. User requirements and information definition for a virtual coastal and marine data warehouse. Ocean & Coastal Management 46: 487-505.

Eleveld MA, Wagtendonk AJ, Pasterkamp R & Omtzigt AQA, 2003. Monitoring North Sea coastal waters: from radiance at sensor data to a Web mapping service. Proceedings CoastGIS 2003, Fifth International Symposium on GIS and Computer Cartography for Coastal Zone Management (Genova, Italy), 9 pp. (CD & URL: http://www.gisig.it/coastgis/).

Esaias E, Abbott M, Barton I, Brown OB, Campbell JW, Carder KL, Clark DK, Evans RH, Hoge FE, Gordon HR, Balch WM, Letelier R. & Minnett PJ, 1998. An overview of MODIS capabilities for ocean science observations. IEEE Trans. Geosci. Remote Sensing 36(4), 1250–1265.

Gittings B (Ed.), 1999. Integrating Information Infrastructures with GI Technology, Innovations in GIS 6, Taylor & Francis, London.

Green D & Bossomaier T, 2002. Online GIS and spatial metadata. Taylor & Francis, London.

Kraak M-J & Brown A, 2001. Web cartography: developments and prospects. Taylor & Francis, London.

McClain CR, Feldman GC & Hooker SB, 2004 Overview of the SeaWiFS project and strategies for producing a climate research quality global ocean bio-optical time series. Deep-Sea Research II 51: 5–42.

Mitchell T, 2005. Web Mapping Illustrated (Using Open Source GIS Toolkits). O' Reilly, Sebastopol (CA).

Nebert D, 2004. Developing Spatial Data Infrastructures: Spatial Data Infrastructure Cookbook v2.0 (January 2004) http://www.gsdi.org/docs2004/Cookbook/cookbookV2.0.pdf

O'Reilly JE, Maritorena S, Siegel DA, O 'Brien MC, Toole D, Mitchell BG, Kahru M, Chavez FP, Strutton P, Cota GF, Hooker SB, McClain CR, Carder KL, Müller-Karger F, Harding L, Magnuson A, Phinney D, Moore GF, Aiken J, Arrigo KR, Letelier R & Culver M, 2000. Ocean color chlorophyll a algorithms for SeaWiFS, OC2, and OC4: Version 4. In: O'Reilly JE, and 24 Co-authors, 2000: SeaWiFS Postlaunch Calibration and Validation Analyses, Part 3. NASA NASA Technical Memorandum 2000-206892, Vol. 11, Chapter 2, pp. 9-23 (NASA Goddard Space Flight Center, Greenbelt, Maryland).

Pasterkamp R., van der Woerd HJ, Peters SWM, Eleveld MA & Roberti H, 2005. Simultaneous determination of suspended sediment and chlorophyll-a: validation for the Dutch North Sea in 2003. Halifax, 8th Conference on Remote Sensing for Marine and Coastal Environments.
Plewe B, 1997. GIS Online: Information Retrieval, Mapping, and the Internet. OnWord Press.
Tsou, M-H, 2004. Integrating Web-based GIS and image processing tools for environmental monitoring and nature resource management. J Geograph Syst 6(2), Special issue on the potential of web-based GIS, pp. 155-174.

URLs (data and software)

- ESRI, ArcScripts. http://arcscripts.esri.com
- Feldman GC, McClain CR, 2005, Ocean Color Web. Eds: Kuring N., Bailey SW, Thomas D, Franz BF, Meister G, Werdell PJ, Eplee RE, MacDonald M, Rubens M, 09 May 2005. NASA Goddard Space Flight Center. Access date: 10 Aug 2005. http://oceancolor.gsfc.nasa.gov/
- IDON (Interdepartmentaal Directeuren Overleg Noordzee), 2004. Noordzee-atlas. Ministerie van Verkeer en Waterstaat / Rijkswaterstaat directie Noordzee, Rijswijk. (on-line available at http://www.noordzeeatlas.nl)
- IVM, WATeRS http://ivm10.ivm.vu.nl/mapserver/WATeRS
- IVM, WATeRS ArcIMS server http://130.37.78.10
- IVM, WATERS in ESRI's ArcIMS standard viewer http://ivm10.ivm.vu.nl/mapserver/waters_defaultviewer
- IVM, WATeRS Metadata
- http://ivm10.ivm.vu.nl/mapserver/waters/metadata/default.html
- IVM, WATeRS Multi-service http://ivm10.ivm.vu.nl/mapserver/waters_multiservice/viewer.htm
- IVM WATeRS WMS ArcIMS-OGC connector http://ivm10.ivm.vu.nl/wmsconnector/com.esri.wms.Esrimap/imageserver_waters2?request=getcapabilities&service=WMS&version=1.1.1 followed by http://ivm10.ivm.vu.nl/wmsconnector/com.esri.wms.Esrimap?BBOX=-2.3254862073,50.3729074938,10.7386643238,58.1123008313&WIDTH=400&HEIGHT=300&SRS=EPSG:4326&Layers=Landen,Binnenwateren,Stedelijke%20gebieden%20Nederland,DEM,Bathymetrie,Rivieren%20Nederland,Rijkswegen%20Nederland,Zandwinning,Concessiegebieden,Baggerstortlocatie,Ankerplaats,Scheepvaart%20patroon,Continentaal%20plat,3%20mijls%20zone,12%20mijls%20zone,Boorplatforms,chloro5,chloro4,chloro3,chloro2,chloro1,Names%20monitoringstations,monitoringstations,&version=1.1.1&service=WMS&FORMAT=JPEG&TRANSPARENT=TRUE&request=getmap&ServiceName=imageserver_waters2
- Rijkswaterstaat, Waterbase. http://www.waterbase.nl/