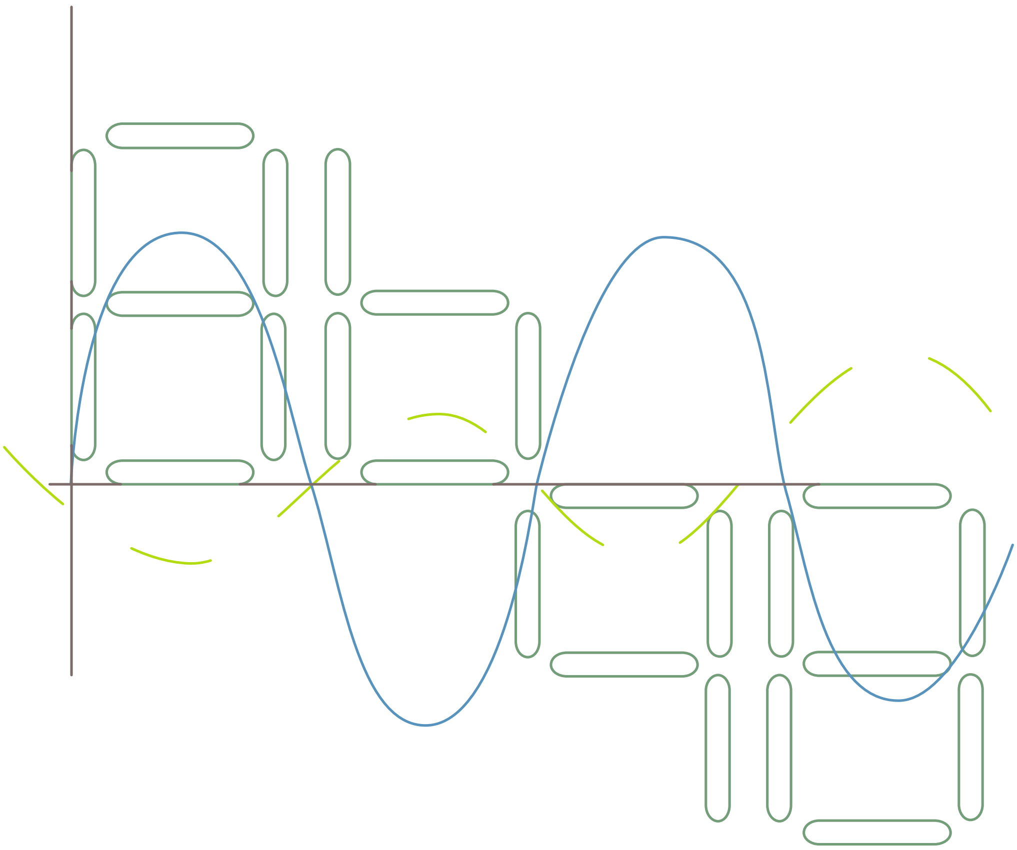
Report 30

GRDC Report Series

Development of an Operational Internet-based Near Real Time Monitoring Tool for Global River Discharge Data

A contribution to the Global Terrestrial Network for Hydrology (GTN-H)



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A contribution to the Global Terrestrial Network for Hydrology (GTN-H)

Thomas Maurer

Global Runoff Data Centre

GRDC operates under the auspices of the World Meteorological Organization (WMO) with the support of the Federal Republic of Germany within the Federal Institute of Hydrology (BfG)

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by:

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1 Summary

The present report describes the achievements of a GRDC contribution to the Global Terrestrial Network for Hydrology (GTN-H), namely the creation of an internet based Near Real Time (NRT) Monitor tool for discharge data (GRDC NRT-Monitor). The core of the project is the development of a software to collect NRT-discharge data from distributed discharge providing sites in the internet and providing it in a harmonised way. Furthermore, an application for graphical display of the collected and harmonised NRT-discharge data, ideally by means of an internet map server (IMS), was to be developed, displaying e.g. the occurrence probability of the currently measured NRT-discharge values based on the long term characteristics.

2 Introduction

2.1 Development of GTN-H

The Global Terrestrial Network for Hydrology (GTN-H) is an initiative of the World Meteorological Organization (WMO) and the Global Climate Observing System (GCOS) that was proposed following an international expert meeting in Geisenheim, Germany, in summer 2000 (GCOS, 2000). The goal is to develop a world-wide near real time (NRT) data reporting scheme of 10 hydrological variables (see figure 1).

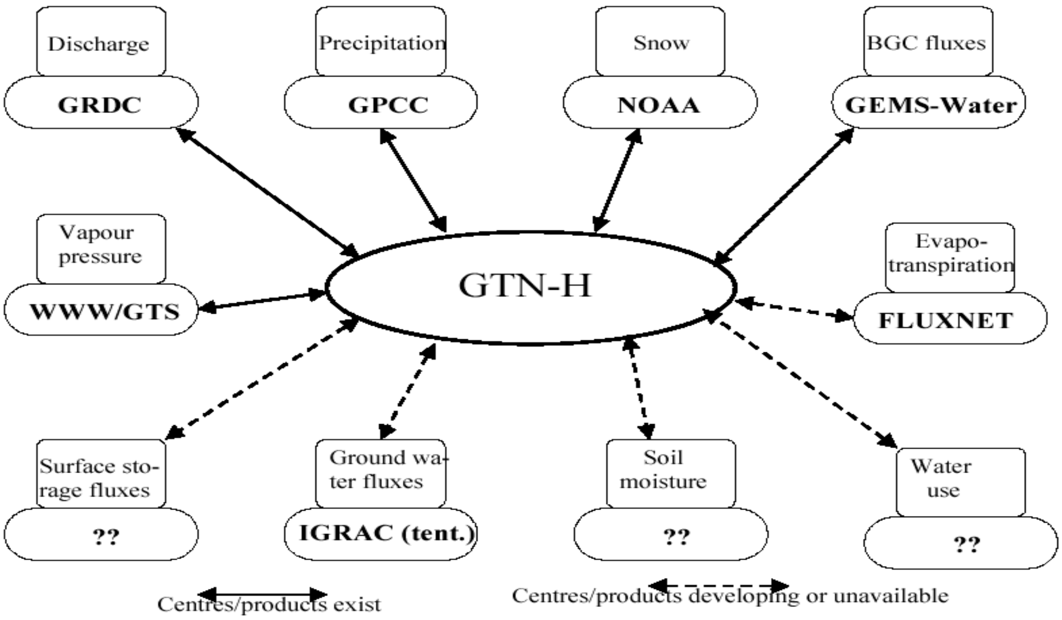


Fig. 1: Basic concept of GTN-H. A network of already existing data centres/networks cares for the individual hydrological variables.

The establishment of the project was noted with appreciation by the Commission for Hydrology (CHy) during its eleventh session in November 2000 (see items 19.1.17-19 of WMO, 2001a). In June 2001 the GTN-H was implemented during a meeting in Koblenz, Germany (GCOS, 2001). In November 2002 a subsequent WMO Expert Meeting on "Hydrological Data for Global Studies" was held in Toronto, Canada (GCOS, 2003a), immediately followed by a meeting of the GTN-H coordination panel (GCOS, 2003b).

2.2 GRDC's role in GTN-H

The Global Runoff Data Centre (GRDC), based at the Bundesanstalt für Gewässerkunde (Federal Institute of Hydrology, BfG) in Koblenz, Germany, and operating under the auspices of the World Meteorological Organization (WMO) participates in GTN-H covering the variable river discharge.

A major contribution of GRDC to GTN-H is the establishment of a world-wide NRT-monitor for river discharge data, consisting of a collector and a visualiser, that will allow to comfortably examine and use global data similar to e.g. what is implemented by the USGS WaterWatch (http://water.usgs.gov/waterwatch) for the United States (i.e. a display of the occurrence probability of the currently measured NRT-discharge values in relation to the long term characteristics).

The benefits of such a project are an easier and unified access to information on NRT discharge data and consequently the demonstration of a best practice example by providing a visible platform for international exchange of hydrological data.

3 Access to river data

3.1 General

As illustrated e.g. in GCOS (2003c), data on geophysical and biochemical processes in the Earth System, including river discharge, is fundamental to many international scientific programs. The larger the spatial scale of interest (local -> regional -> global) and the more complex the modelling approaches, the more important is a reliable and well organised data acquisition and integration strategy, in order to prevent stagnation due to the dilemma of either redundantly spending too much of valuable resources (time, money...) retrieving basic data or, alternatively, omitting relevant information.

Problems exist especially in the terrestrial domain. Monitoring of processes on the inhabited land surface is organised highly heterogeneously by a huge variety of administrational systems on different scales (continents, countries, regions...). Moreover, responsibilities are usually fragmented among different sectors (water, energy, transport, forest...). This is especially obvious in the field of hydrology, were multifold problems on availability and access to hydrological data and especially runoff data remain in spite of WMO Resolutions which call for free and unrestricted exchange of hydrological data (WMO Resolution 25 (Cg-XIII), 1999, see also WMO, 2001b+c) and support of GRDC's mission (WMO Resolution 21 (Cg-XII), 1995). The following lists the major problems, while in parenthesis the underlying main problem is indicated, though almost all problem types are interconnected:

- Inadequate exchange of available data (political problem)
- Fragmented data holdings (technological problem)
- Lag time in data processing and provision (organisational problem)
- Declining networks (financial problem)
- Quality of data (scientific problem)

Statistics on GRDC discharge data acquisition activities that were started in 2001 revealed that GRDC has around 240 contacts per year to 40 countries (in average 6 contacts per country). Out of this, around one third result in a successful data acquisition (i.e. 13 countries/year and in average 18 contacts per successful data acquisition). This success rate results in a database time lag that does not allow to come up with up-to-date and purely measurement based global monitoring products, as e.g. the GRDC-Product "Long Term Mean Annual Freshwater Surface Water Fluxes into the World Oceans".
With respect to their discharge data provision discipline to GRDC the around 180 countries of the world can be classified in four groups, namely countries that

1. send data without request (basically: USA, Canada, Norway, Iceland, Australia)
2. send data on single or few requests (~10-20%)
3. send data after long lasting negotiations (~50-70%)
4. do not send data for various reasons (~20-30%)

Given the typical configuration of data centres like the GRDC (GRDC staff comprises 2 academics and 2 technicians, as well as a part time administrational assistance; of this staff two persons spend around 33% of their time for data acquisition by contacting individual countries), this is not likely to improve significantly without fundamental changes. Figur 2 shows the temporal distribution of the number of stations in the GRDC database as well as its progress over time in six month intervals. The current project aims at filling up the gap between the peak of the distribution and today.

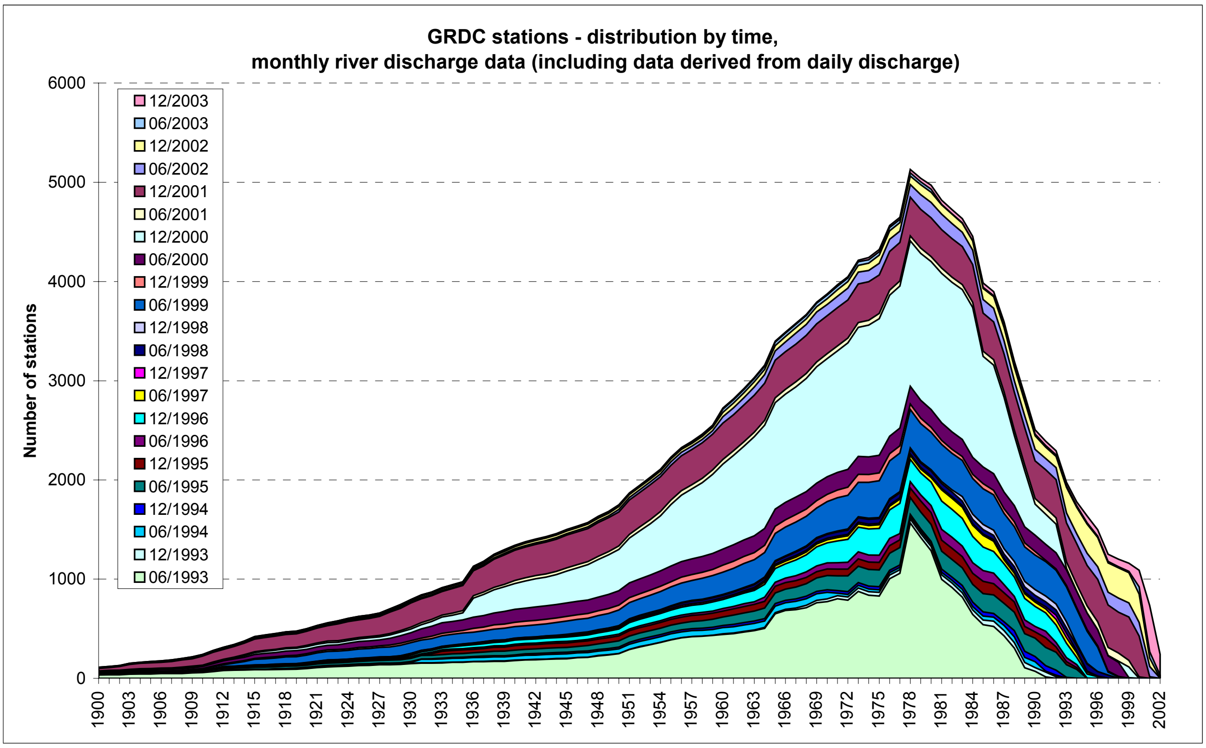


Fig.2: Temporal distribution of the number of stations in the GRDC database as well as its progress over time in six month intervals

3.2 Near real time river data

Modern information technology in principle provides a means to improve accessibility of data. In fact today a considerable number of National Hydrological Services (NHS) or similar official authorities offer online river data in one or the other way. GRDC has collected a list of these online services (annex 1). The number of stations thus reported online is depicted in figure 3 for the world and in figure 4 as a close-up for Europe. Some of the data is related to individual countries and provided by their NHSs, other data is provided by regional observing systems like Med-HYCOS in the Mediterranean region or SADC-HYCOS in the Southern African region.

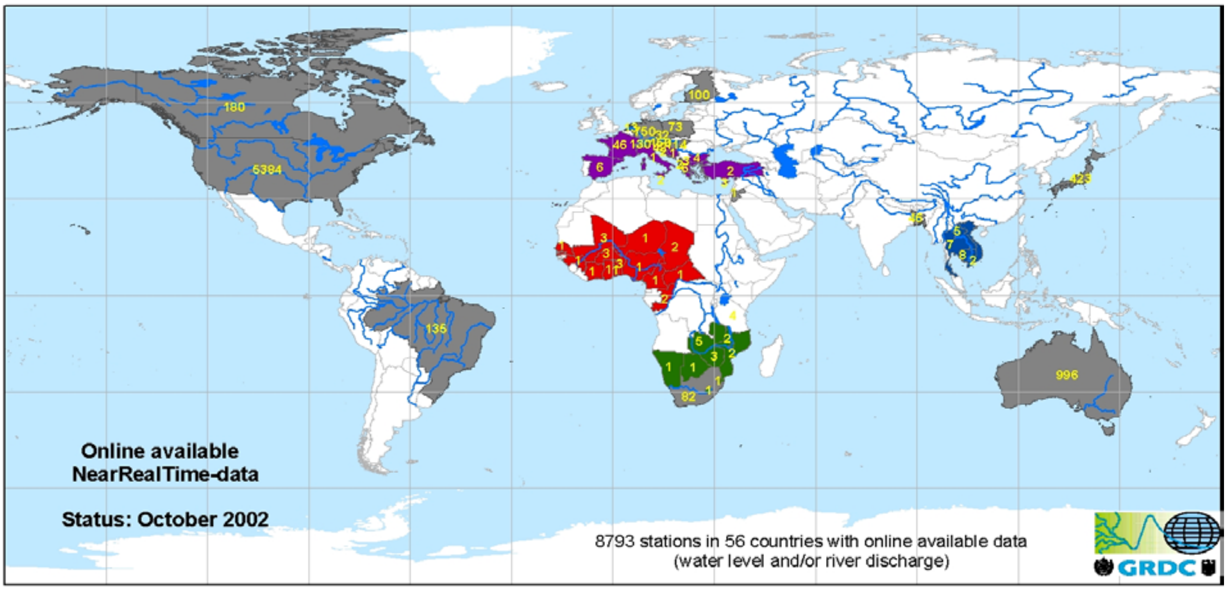


Fig. 3: Overview of number of stations for which river discharge or water level data is provided online (world).

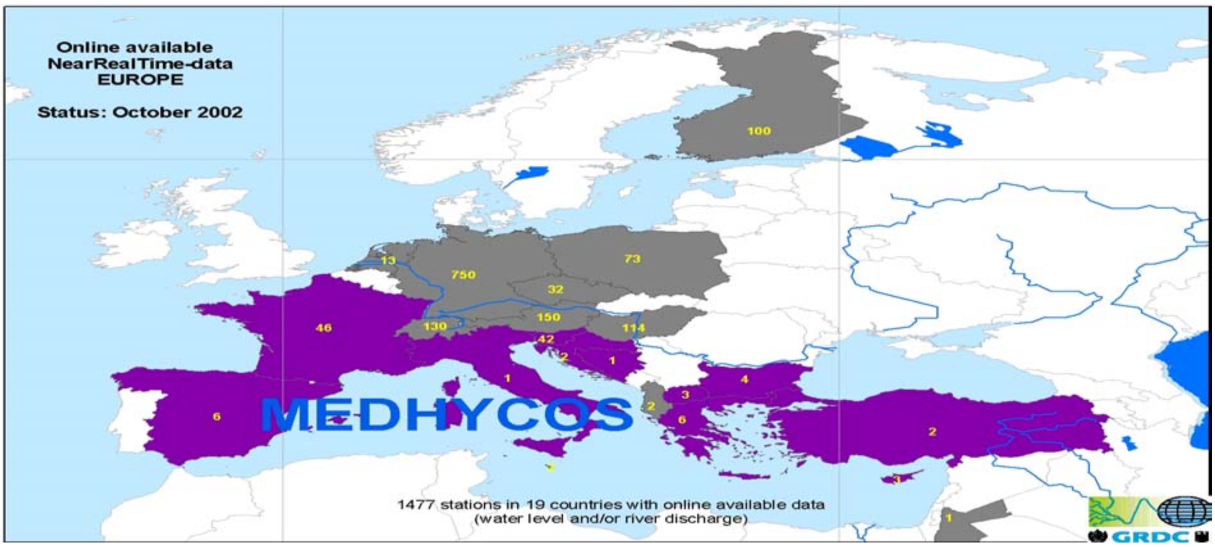


Fig. 4: Overview of number of stations for which river discharge or water level data is provided online (Europe).

However, close examination of these services reveals a fundamental problem of the current practice, i.e. the data provided is heterogeneous in many respects.

- Data type
    - Discharge
    - Water levels

- Time structure
    - Many values per day (e.g. hourly)
    - One value per day (at some fixed time)
    - Daily statistics (min, mean, max)

- Access structure
    - Zip-archives
    - Grouped by country, river basin, region year,...
    - Via search engines or search forms
    - Various types of metadata available or not

- Access style
    - ASCII-tables
    - HTML-tables
    - HTML-pages
    - Tables as bitmaps
    - Values in bitmaps
    - Hydrograph as bitmaps

Hereof countless combinations are possible and actually available in the real world! Moreover, experience shows that due to the high dynamics of online resources it is most likely, that parts of the information in any kind of compilation are already re-organised or out-of-date while other recent changes are yet missing by the time the compilation is being used.

The GRDC thus provides the list in annex 1 "as is", tagging each entry with its date of compilation. Maintaining such a list is a task that easily adsorbs 25-50% of the working capacity of a skilled specialist. This demonstrates that a sustainable solution can only be achieved making use of the potential of standardisation of interchange information elements and formats.

4 Standardisation

4.1 Sound steps towards information integration

Good software engineering practices teach that a fundamental prerequisite for any good computer programme (e.g. describing the Earth System) is a systematic approach that sticks to an order of sub-problems to be solved (if necessary repeatedly in iterative cycles, see e.g. Sommerville, 1995):

1. find out the information needs and the corresponding sources
2. find out how to store the required information
3. find out how to access the information and prepare access routines
4. develop the functional routines after having designed the data structure as the core element of a sound and extendable system.

The crucial point here is the order. If one fails to follow this sequence and e.g. starts off with step 4 as it too often happens in over-haste ("quick and dirty"-programming) the results are likely to become intricate and after a while cannot be extended any further due to structural shortcomings. In computer programming such approaches are frequently called "spaghetti-code" using the metaphorical expression as a synonym for a chaotic and intricate structure.

However it is by far neither an easy task to define all information needs prior to the development of complex models nor to locate the relevant sources or ensure that all sources have been considered. At this point, frequently the call for Environmental Information Systems (EIS) and meta-database systems is raised.

Even more difficult on a larger scale is the design of generalised storage schemes and access routines to the information, designed for shared application by many users. Here again a dilemma is encountered:

- On the one may work together from the start in an expensive coordinated effort to develop non-proprietary open standards, an enterprise which always bears the potential to collapse beyond a certain scale
  - (a) because it may run out of resources prior to proving its usefulness by relieving enough potential supporters from significant problems or
  - (b) because the technical progress out-dates the developments faster than they are evolving.
- Alternatively, one may start developing relatively small proprietary stand-alone-solutions which are easy to control at first, but usually lead to insuperable problems when attempting to combine too many of them in a multidisciplinary effort.

4.2 The case of geomatics (ISO/TC 211)

There have been considerable recent achievements in the field of standardisation of data and metadata representation and transfer, especially in the field of geomatics. The ISO Technical Committee 211: Geographic Information/Geomatics (ISO/TC 211) is developing a set of standards (ISO 19106-19118) in the field of digital geographic information, aiming to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth (as are also all measurements taken of state variables of geophysical processes including water–related ones!)

In May 2003 their metadata standard ISO 19115 has been released, as a result of long consultations of organisations pioneering this field, among them in a leading role the US Federal Geographic Data Committee (FGDC) and other members of the OpenGIS Consortium.

ISO 19115 defines more then 300 metadata elements (classes, attributes, relations), most of which can be applied optionally. The structure and relationships between the components are shown using 14 UML diagrams and the definitions given in a tabulated dictionary in 14 sections. Both the UML and dictionary are normative. The entities or classes are grouped in 5 packages, Metadata, Lineage and Data Quality, Extent and Citation, which are thus also available for use in other TC 211 standards as appropriate. The obligation of the various entities or classes is quite variable and flexible, and the structure of ISO 19115 metadata is complex.

The scope of the information covered by ISO 19115 is broadly that needed for a user to identify, evaluate, select, obtain, and possibly use the datasets described. The level of detail is much greater than other standards and the manner in which it is provided is much more structured. The content models are elaborate and hierarchical, and for those elements that still contain text, the information is generally disaggregated more finely. This supports the construction of more elaborate interfaces and more finely controlled queries, but places a much greater burden on the metadata provider and tool developer. ISO 19115 attempt to cover the needs of a wide range of potential applications, but at the cost of a rather daunting structure. Rules are given on how to define a community or domain profile which limits the elements used or the values or obligations of components of the standard, and also on how to add specialised extensions where it is found that the requirements are not satisfied by the components already defined in ISO 19115 (though the need for the latter is considered minimal and clearly discouraged!).

However, the ISO 19115 specification also summarises the generic core metadata comprising the minimum elements that satisfy the requirements of an ISO conformant metadata record. Examples of core metadata records end up containing a comparable amount of information as a typical record by other standards (i.e. 20-40 entries).

Overall, ISO 19115 aims to define a comprehensive range of metadata elements that may be needed, so that any single application domain will normally select only a subset of the components available. E.g., WMO (2002) has developed a ISO 19115 compatible profile called the WMO Core Metadata Standard based on XML.

The OpenGIS Consortium aims to provide a comprehensive suite of open interface specifications to enable transparent access to heterogeneous geo-data and geo-processing resources in a networked environment. They work on the implementation of these standards applying the Extensible Markup Language (XML), which is an internet standard approved by the World Wide Web Consortium (W3C) allowing the separate definition of the logical and physical structure of a documentation object.

4.3 Architecture for data and information integration systems

Standards usually cover a sector and still are not necessarily accepted or implemented everywhere on a global scale. The reasons for this are manifold and are related to the heterogeneity discussed in earlier sections.

Denzer et al. (1993, 1995b) have pointed out clearly in the context of developing Environmental Information Systems (EIS) that no matter how much effort will be invested to integrate distributed and heterogeneously spread information of different meaning, syntax and structure, from a practical point of view there is no realistic way to combine them in a single unified system in a reasonable time frame. According to Denzer et al. (1993, 1995b) this is due to mainly three reasons, namely heterogeneity, autonomy and dynamics. Their thoughts are illustrated below:

Heterogeneity: In practice, different systems to be integrated are heterogeneous in different respects:

1. Syntactical heterogeneity means that systems differ with respect to hardware, operating system, storage technology etc. Syntactical heterogeneity is a pure computer problem and should be hidden from the user.
2. Semantical heterogeneity means that there are different notions about the semantics of a single piece of information. This includes the development of different terminologies in parallel projects in different regions.
3. Structural heterogeneity evolves due to the fact that different parties combine different sets of simple information to different structures (or objects) denoting the same type of information, but in a different way, resulting in aggregates of different syntax and different meaning (although some part of these objects may have the same meaning).

Autonomy: Many EIS which have been built are information systems for public authorities, supporting public services in their every day work. Due to the legal authority of these institutions, they are completely autonomous in their decisions concerning information technology. Due to scattered sectoral and regional competencies with regard to environmental management one is confronted with a fragmented situation of approaches in different regions and subregions. This holds especially true for water as a traditionally locally managed resource in many regions of the world..

The task of building a data network in such a situation means, that it is not possible to apply a unique data model for such a network because one can never force anyone to use this data model or stick to it and its enhancements..

Software developers have to accept the fact that fragmented autonomy is something that will not vanish quickly. This makes integration more difficult but not impossible, i.e. this boundary condition has severe implications on the types of software architectures which can apply to autonomous systems.

Dynamics: It is usually impossible to thoroughly describe the tasks ahead in environmental management in a single step from scratch, and this consequently holds true for the definition of a final data model too. Even if a perfect data model could be defined beforehand, it is unlikely that this model remains valid for more than one year, given the rapidly changing demands. Thinking of the integration of hundreds of environmental data sources and linking them with hundreds of thousands of potential clients, it becomes clear what it means to keep such a system up-to-date when data sources change their features all the time.

4.4 Example SIRIUS

To overcome these problems Denzer et al. (1993, 1995a, 1995b, 1998, 2000) developed an Environmental Information System (EIS) that serves as a meta-database system and as data retrieval system capable to integrate distributed existing database systems of different structure and level of abstraction without touching their grown internal structure nor necessarily their ownership, i.e. control of local administrators. This system features a flexible internet based client server architecture that ensures applicability across heterogeneous environments. The system is designed in a completely generic way by means of a communication server (termed SIRIUS, Denzer et al. 1995a) between local service programmes and distributed clients, which thus features two interfaces. The system is furthermore prepared to automatically translate all features client-dependently.

Different local systems feature different levels of abstraction; few of them give access to their catalogues, almost none of them is able to describe itself, e.g. by object-classes and structures they provide. To enable the outer world nevertheless to see what local systems have to offer in a unified way, each local system participating has to be equipped with a slim local interfacing database and a number of service applications running on the local system communicating with the communication server. These are the only parts of the system which have to be adjusted and have to restrict to some standards of the system. The local interfacing database can be regarded as the "table of contents" of the local database designated for integration and remains completely under the control and responsibility of the local administration. It defines who is permitted to view or retrieve what information and also contains the methods how to access the local system for retrieval. Once a local candidate system is set up as described its data is readily available to the outer world.

On the client side of the system the only prerequisite is a WWW-browser. A JAVA-application collects all meta-information which a user is authorised to view from the communication server and jointly displays it as a multi-hierarchical tree from which single data sets can be selected.. Alternatively the interface also allows to selectively query the metadata including location, which can be both, selected and displayed, in an integrated internet map server window.

A system like the one described by Denzer et al. (1993, 1995a, 1995b, 1998, 2000) provides the slimmest possible approach to integration by ideally combining centralised and decentralised features, thus being flexible enough to be adjusted with minimal effort to the ever changing boundary conditions as discussed above. Recapitulating, the introduction of a new data-source in the system is thus achieved

- without making changes or enhancements to the communication server;
- without making changes or enhancements to the clients, i.e. all end-user applications;
- without having to write too much new code for each new data source.

4.5 Example MERCURY

Even though Denzer et al. (1993, 1995b) was among the first to promote the ideas outlined above, there are other initiatives around showing developments along similar lines, e.g. the MERCURY approach for scientific data management launched at the Oak Ridge National Laboratory, a federal research facility operated by Lockheed Martin Energy Research Corporation for the US Department of Energy. This metadata management scheme builds on existing WWW technology and commercial-of-the-shelf (COTS) products as well as on agreed metadata standards. The basic idea here is to keep metadata sets in XML format on the servers of providers and likewise their maintenance in the hands of the providers who also maintain a "locator file" (the table of contents!) at their system. This "locator file" has to be registered with the Mercury system. Based on these registrations a specialised Mercury web-crawler extracts the latest versions of metadata sets in nightly "harvesting"-runs and stores them in a central database, which again is made available to the public by a web-browser application. Several US organisations already joined the system.

5 Methodology

5.1 General

In the light of the elaboration in the previous chapters on data acquisition and standardisation and in view of limited time and capacity in the scope of the current project to come up with the GRDC NRT discharge data monitor a pragmatic decision had to be made. It was clear from the beginning, that a general standardised interface for the transfer of NRT discharge data would not be available during the project. Also, given the described difficulties in contact with the data providers GRDC did not expect to arrive at one exchange format. The project has been designed to provide a mechanism to join data from heterogeneous sources. The project has been split into two principle tasks, development of the data collector and development of the data visualiser as explained in the subsequent sections.

5.2 Data collector

The data collector is a modular and scalable software that collects global near real time river discharge data from distributed FTP-sites in the internet, stores it in a database and makes it instantly available in a harmonised way via FTP (see figure 5). Special attention was required to produce a robust software, prepared to cope with all kinds of possible sources of errors or disturbances as they are likely to occur in a real world global data provision context.

As not all potential data providers will be connected to the system from the beginning of the project the development of a simulated distributed network of data providers was required in order to enable thorough testing of the software, including the simulation of imaginable errors or disturbances.

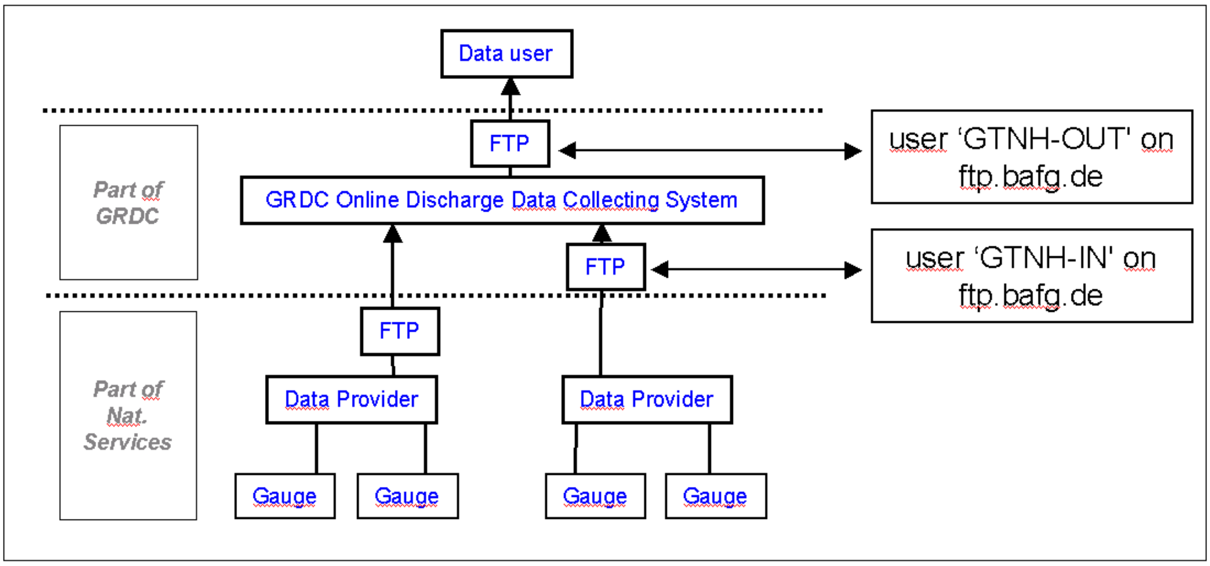


Fig. 5: Schematic showing the concept of the data transfer mechanisms in GTN-H for river discharge data

Due to the lack of standardisation of interchange formats and the partial reluctance of data providers to deliver their information in other than their proprietary data formats an extendable interface of a variety of format converters had to be developed.

5.3 Data visualiser

The data visualiser is designed to display the collected and harmonised near real time river discharge data in a map, together with analyses of possibly available historical data, thus allowing to show e.g. the occurance probability of a NRT value. The visualiser so far is a stand alone computer aplication, however, it is planned to display the maps dynamically in a web page by means of an internet map server or equivalent.

6 Product

The concept of the GRDC NRT Discharge Data Collector as depicted in figure requires:

- Regular NRT provision of discharge data in a agreed format on either a remote or the BfG-data exchange FTP-site by contributing NHS
- Regular data collection cycles by GRDC, data harmonisation and export of the harmonised data to the BfG data exchange FTP-site

For this purpose a management software has been developed as a Delphi client-server-application connecting to an Access or Oracle-database. The major features are illustrated in figure 6. After a user login and the selection of either a manual or an automatic mode, it is possible to add details of FTP-sites that are provided with NRT discharge data by NHSs. The appropriate data import routine is selected according to the agreements made with the data providers (and had to be implemented in the software prior to its use). In automatic mode the FTP-sites are now visited according to the adjustments of a build-in timer control.

In predefined intervals the harmonised data is now exported in 2 ASCII-files with discharge values respectively metadata and provided for user application on the output FTP-site. The data-formats are illustrated in figure 7.

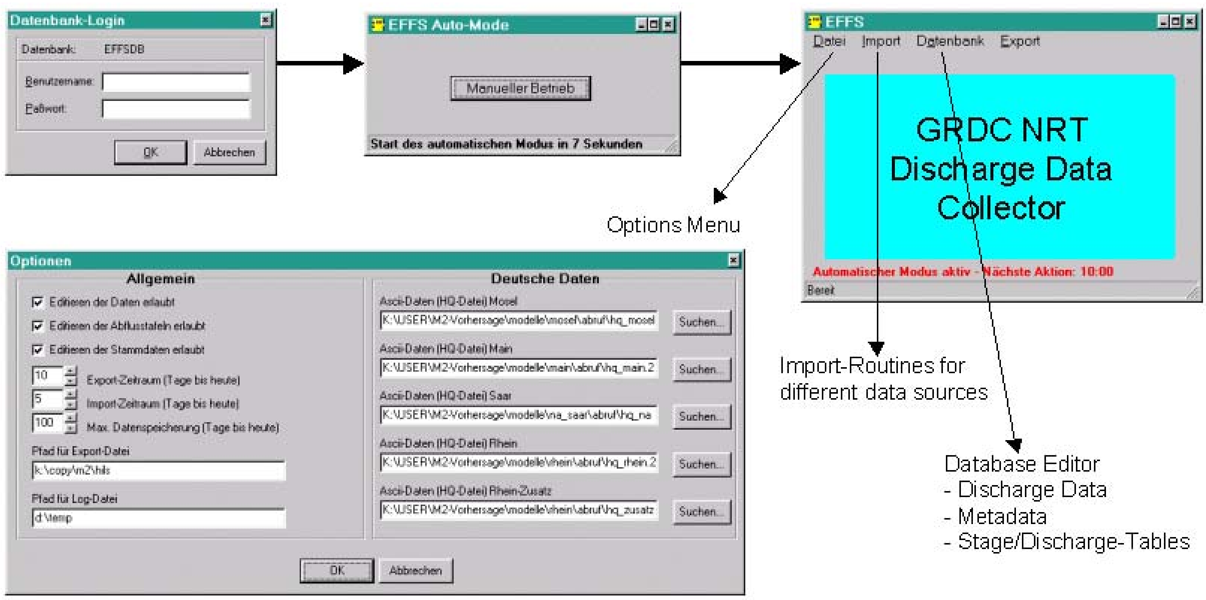
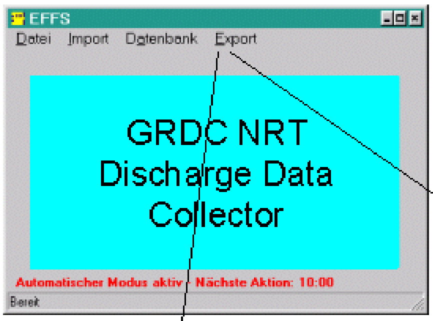


Fig. 6: User interface of the management environment of the GRDC NRT Discharge Data Collector



Exportfile - Discharge Data

```
******ATTENTION: ALL VALUES PROVISIONAL - NOT VERIFIED!******
EFFS No; Short Name
YYYY.MM.DD HH:MM; Discharge(m**3/s)
0000001;Rhein_Max
2001.09.27 02:00;1699
2001.09.27 03:00;1699
2001.09.27 04:00;1693
2001.09.27 04:45;1693
2001.09.27 05:30;1686
0000014;Aare_Brugg
2001.09.25 05:00;375.07
2001.09.26 04:50;399.05
2001.09.27 04:50;384.8
0000015;Ticino_Bellinzona
2001.09.21 03:05;30.77
2001.09.25 03:20;36.98
2001.09.26 03:10;42.62
2001.09.27 03:10;40.23
0000016;Neckar_RockenauSKA
2001.09.26 08:00;119
2001.09.26 09:00;121
0000017;Thur_Andelfingen
....
```

Exportfile - Metadata

```
EFFSNo;River;Station;ShortName;Lat;Lon;Area;Country;Basin1;Basin2;Basin3;Basin4
0000001;Rhein;Maxau;Rhein_Max;49.0359992980957;8.33500003814697;50196;Deutschland;Rhein;;;
0000002;Rhein;Speyer;Rhein_Speyer;49.3359985351562;8.42500019073486;53131;Deutschland;Rhein;;;
0000003;Rhein;Worms;Rhein_Worms;49.6220016479492;8.34899997711182;68827;Deutschland;Rhein;;;
0000004;Rhein;Mainz;Rhein_Mainz;49.9910011291504;8.26399993896484;98206;Deutschland;Rhein;;;
0000014;Aare;Brugg;Aare_Brugg;47.4599990844727;8.17000007629395;11750;Schweiz;Rhein;Aare;;
0000015;Ticino;Bellinzona;Ticino_Bellinzona;45.6399993896484;9.02999973297119;1515;Schweiz;Rhein;;;
0000016;Neckar;Rockenau_SKA;Neckar_RockenauSKA;49.423999786377;8.97799968719482;12710;Deutschland;Rhein;Neckar;;

.........

.........
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Fig. 7: Export data sets after harmonisation of the various input data sets

The data visualiser, which is an GRDC application accesses these output files. Using additional data (e.g. historical data, alarm values etc) the data visualiser allows to diplay maps and hydrographs of river discharge conditions as illustrated in figures 8 and 9 for the case of the Rhine basin and Poland, respectively.

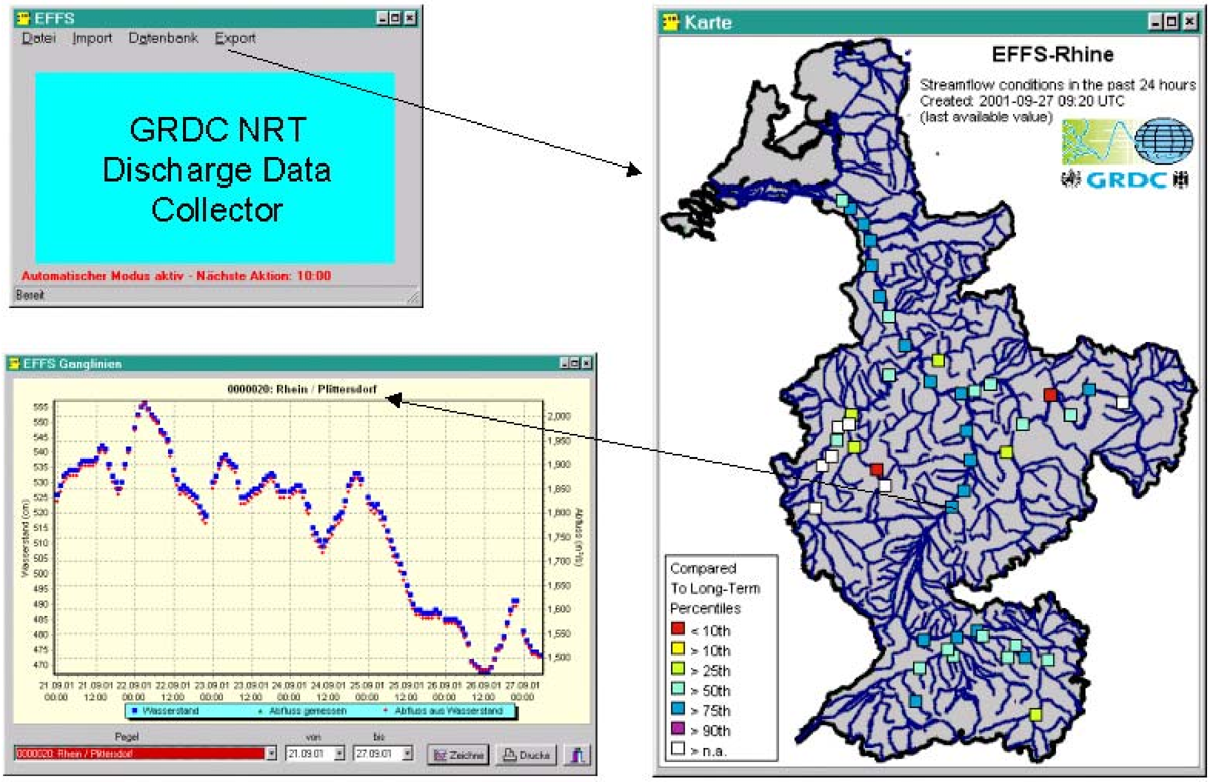

Fig. 8: Example Rhine basin: visualisation of export data sets: relation of NRT discharge data to long term percentiles in map, hydrograph of individual stations

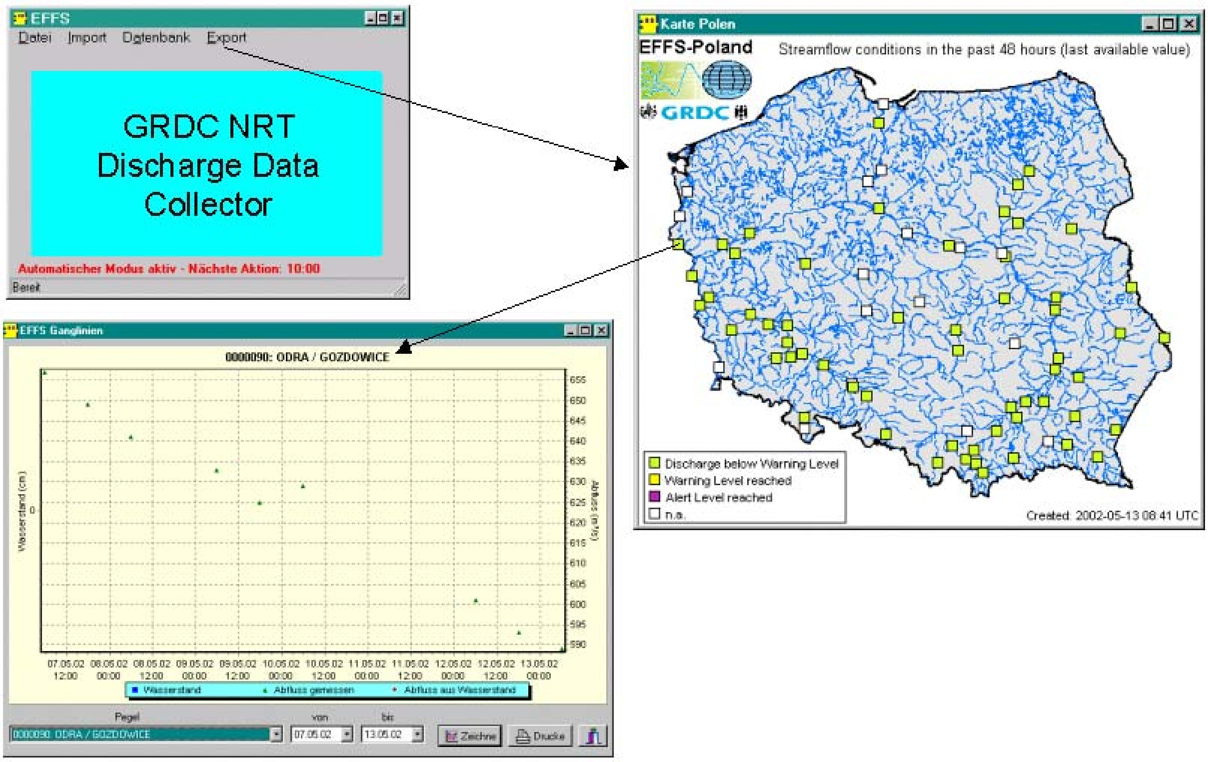

Fig. 9: Example Poland: visualisation of export data sets: relation of NRT discharge data to warning levels in map, hydrograph of individual stations

7 Conclusion and Outlook

7.1 Further Development

The GRDC NRT monitor as described in the previous sections has to be regarded as the start of a ongoing process to be further developed for a variety of reasons:

- The preparedness of collaborating organisations (like NHSs, river basin authorities, WHYCOS-networks, etc) has to be raised and increasingly more providers have to be included over time.
- The system has to be maintained and further advanced using up-to-date software tools, as e.g. an Internet Map Server (IMS). Thus it will serve as an best-practise example.
- More applications of the GRDC NRT monitor system have to be developed in order to demonstrate its potential and thus especially to raise the preparedness of data providers for contributions. The GTNH NRT discharge data visualiser is a good example.

Especially for the improvement of the situation regarding the first bullet item further action has to be taken as described in the following subsections.

7.2 Required long term vision

To sustainably overcome the data acquisition related nuisances and its associated problems it is essential to tackle two issues (which are beyond immediate GRDC scope):

1. Investment of a higher percentage of the total resources at disposal of all the international organizations, programs and projects in the field of Global Change research (on climate, environment, demographic development...) in reaching for the fundamental long term goal "Ensuring the Knowledge Base", what is Challenge 10 of the World Water Development Report (WWDR, 2003). Meeting this goal is a basic prerequisite for coping with most of the other challenges! It requires a statesman's VISION with a perspective of 10-30 years rather than a politician's VIEW, tied to (re-)election-cycles or the next project report deadline in 3-5 years.

   Activities to ensure the knowledge base generates almost necessarily additional overhead, just like libraries do in the world of books. However, as a fundamental prerequisite for further integration we need to come up with comfortable, unified, easy-to-access "libraries" for valuable data costly gained from monitoring geophysical processes. This in turn inevitably require international standardisation as already achieved in library science (cf. next section). (All major global businesses, including telecommunication, finance, military, in the long term only succeed because of standardisation, in fact the "success story" of mankind's development can be viewed as a history of standardisation of networks, technical equipment etc., removing "friction losses" in interaction...).

2. Proactive contribution to sensitively convincing the political level (the world's governments) of the need to anticipatory invest more and/or more systematic in data integration. This includes enforcement of data integration by setting up reporting obligations in the framework of conventions or the like, i.e. controlling feedback-loops at the international-national and the national-sub-national interfaces, in order to enforce a feedback mechanism and thus to ensure at least approaching the vision.

It is encouraging in this context to read the conclusions of "The Second Report on the Adequacy of the Global Climate Observing Systems" GCOS (2003c). Other encouraging developments are the recent Earth Observation Summit (EOS, http://www.earthobservationsummit.gov) in Washington and the Integrated Global Observing Strategy Partnership (IGOS-P, http://www.igospartners.org).

7.3 Perspectives for GRDC operation

In order to achieve the GRDC contributions to GTN-H to prosper more dynamically there are three principal options or measures to improve GRDC's performance:

1. Increase of internal capacity
   - e.g. fund raising allowing to employ additional staff for a multiplication of the current data acquisition practice ("brute force" approach)
   - e.g. fund raising allowing to employ additional staff for increased communication efforts necessary for the advancement of innovative projects as e.g. near real time discharge data integration in the framework of the Global Terrestrial Network for Hydrology (GTN-H).
2. Increase of external capacity
   - Outsourcing of tasks (however some managerial capacity cannot be outsourced):
   - Data acquisition: proactive involvement of all kinds of international organisations, programmes and projects, as e.g. GEWEX, CliC etc.
   - Data analysis: proactive involvement of all kinds of international organisations, programmes and projects and proactive cooperation with research institutions analysing GRDC data (currently 6 under way)

- Data products: proactive cooperation with research institutions using GRDC data

3. Foster automation
   - Automation of internal and external processes
   - Inevitably linked to standardisation of data formats and transfer and storage schemes, needs to be coordinated internationally
   - Experiences gained in the field of Geomatics, which came up with a suite of ISO standards on geographic information objects (e.g. ISO 19115 on metadata) may serve as a basis and template (regarding the standards as well as the organisational processes leading to the standards)

8 References

8.1 Literature

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8.2 Acronyms and Links

DCMI, Dublin Core Metadata Initiative: Homepage, http://dublincore.org

FGDC, Federal Geographic Data Committee: Homepage, http://www.fgdc.gov

ISO/TC 211 Geomatics: Homepage, http://www.isotc211.org

HWRP, Hydrology and Water Resources Programme of the World Meteorological Organisation: Homepage, http://www.wmo.ch/web/homs/hwrphome.html

OGC, Open GIS Consortium: Homepage, http://www.opengis.org

WWAP, World Water Assessment Programme: Homepage, http://www.unesco.org/water/wwap

XML, Extensible markup language: Homepage, http://www.xml.org

Annex 1

List of near real time river stage and/or discharge providing online resources

Annex 1 List of near real time river stage and/or discharge providing online resources

Country	Institution	URL	Last visit	Kind of Data	Type of Data	Form of Data	Resolution	Number of Stations	Display	Language	Access	available by	Download	Coordinates
ALBANIA	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	18.11.03	water level	current year	mean	hourly	2	graph + table	english	on request	single station	on request	available
ANGOLA	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	4	graph + table	english	paste and copy text	single station	on request	not available
ARGENTINA	INSTITUTO NACIONAL DEL AGUA	http://www.ina.gov.ar/alerta/CUADRO.htm	19.11.03	water level	actual day	mean	daily	51	table	national language	paste and copy text	single station	no	not available
AUSTRALIA	Water and Rivers Commission in Western Australia	http://www.wrc.wa.gov.au/waterinf/telem/table.htm	19.11.03	water level	actual day	instant	daily	135	graph + table	english	paste and copy text	single station	yes	not available
AUSTRALIA	Manly Hydraulics Laboratory	http://marlin.mhl.nsw.gov.au/www/dcol.htmlx	19.11.03	water level	last month	mean	continuously	6	hydrograph	english	paste and copy text	single station	no	not available
AUSTRALIA	Commonwealth Bureau of Meteorology	http://www.bom.gov.au/hydro/flood/nsw/rain_river.shtml	19.11.03	water level	actual day	instant	continuously	890	table	english	paste and copy text	single station	no	available
AUSTRIA	Hydrographischer Dienst Oberösterreich	http://www.ooe.gv.at/hydro/index.htm	19.11.03	water level	actual day	instant	daily	16	hydrograph	national language	text picture	single station	no	not available
AUSTRIA	Amt der Steiermärkischen	http://www.stmk.gv.at/verwaltung/fa3a/REF1d.stm	19.11.03	water level	actual day	instant	continuously	39	table	national language	paste and copy text	single station	no	not available
AUSTRIA	Landesregierung Kärnten, Abt.: Wasserwirtschaft	http://www.wasser.ktn.gv.at/	19.11.03	water level	actual day	mean	daily	22	hydrograph	national language	text picture	single station	no	not available
AUSTRIA	Landeswasserbauamt Vorarlberg	http://www.vorarlberg.at/vorarlberg/umwelt_zukunft/umwelt/landeswasserbauamt/abteilungen/hydrographie/weitereinformationen/wasserstaende-bodensee_al/messwerte-wasserstaende.htm	19.11.03	water level	actual day	instant	hourly	6	graph + table	national language	text picture	single station	no	not available
AUSTRIA	Land Niederösterreich (Lower Austria)	http://www.noel.gv.at/service/wa/wa5/htm/wnd.htm	19.11.03	water level	actual day	instant	hourly	25	graph + table	national language	text picture	single station	no	not available
AUSTRIA	Salzburger Landesregierung	http://www.salzburg.gv.at/themen/nuw/wasserwirtschaft/64-hydrographie/hochwasser.htm	19.11.03	water level	current year	instant	daily	7	graph + table	national language	text picture	single station	no	not available
AUSTRIA	Landesregierung Tirol	http://www.tirol.gv.at/themen/umwelt/wasser/wasserkreislauf/wasserstand/hwpegel.shtml	19.11.03	water level	actual day	instant	daily	43	hydrograph	national language	text picture	single station	no	not available
BANGLADESH	Flood Forecasting and Warning Centre	http://www.ffwc.net	19.11.03	water level	last month	mean	daily	100	graph + table	english	paste and copy text	single station	no	not available

Annex 1 List of near real time river stage and/or discharge providing online resources

Country	Institution	URL	Last visit	Kind of Data	Type of Data	Form of Data	Resolution	Number of Stations	Display	Language	Access	available by	Download	Coordinates
BELGIUM	Direction des Cours d'Eau non navigables	http://mrw.wallonie.be/dgrne/aqualim/	19.11.03	river discharge	last month	mean	hourly	100	hydrograph	french	text picture	single station	no	available
BELGIUM	Direction des Cours d'Eau non navigables	http://mrw.wallonie.be/dgrne/aqualim/	19.11.03	water level	last month	mean	hourly	100	hydrograph	french	text picture	single station	no	available
BELIZE	Belize National Meteorological Service	http://www.hydromet.gov.bz/	27.10.03	river discharge	current year	mean	daily	15	station map	english	on request	single station	on request	not available
BELIZE	Belize National Meteorological Service	http://www.hydromet.gov.bz/	27.10.03	water level	current year	mean	daily	15	station map	english	on request	single station	on request	not available
BOSNIA AND HERZEGOVINA	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	18.11.03	water level	current year	mean	hourly	1	graph + table	english	on request	single station	on request	available
BOTSWANA	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	11	graph + table	english	paste and copy text	single station	on request	not available
BULGARIA	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	18.11.03	water level	current year	mean	hourly	5	graph + table	english	on request	single station	on request	available
BULGARIA	National Institute of Meteorology and Hydrology	http://www.meteo.bg/new_web/main_en.html	21.11.03	water level	last month	mean	monthly	63	station map	national language	display only	single station	no	not available
CAMBODIA	Mekong River Commission	http://www.mrcmekong.org/	19.11.03	river discharge	last week	mean	daily	11	graph + table	english	paste and copy text	single station	yes	not available
CAMBODIA	Mekong River Commission	http://www.mrcmekong.org/	19.11.03	water level	last week	mean	daily	23	graph + table	english	paste and copy text	single station	yes	not available
CANADA	Water Branch Manitoba	http://www.gov.mb.ca/natres/watres/river_report.html	24.11.03	river discharge	current year	mean	weekly	22	hydrograph	english	text picture	single station	yes	not available
CANADA	Government of Alberta	http://www3.gov.ab.ca/env/water/basins/basinform.cfm	24.11.03	river discharge	current year	mean	daily	234	graph + table	english	paste and copy text	single station	no	not available
CANADA	SaskWater	http://www.saskwater.com/	24.11.03	river discharge	current year	mean	daily	33	hydrograph	english	text picture	single station	no	not available
CANADA	Water Survey of Canada	http://scitech.pyr.ec.gc.ca/water/Map.asp	27.10.03	river discharge	actual day	instant	continuously	1127	hydrograph	english	text picture	single station	no	not available
CROATIA	Meteorological and Hydrological Service	http://hidro.hr/hidro_en.html	24.11.03	river discharge	actual day	mean	daily	28	table	english	paste and copy text	single station	no	not available
CROATIA	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	18.11.03	water level	current year	mean	hourly	2	graph + table	english	on request	single station	on request	available
CROATIA	Meteorological and Hydrological Service	http://hidro.hr/hidro_en.html	24.11.03	water level	actual day	mean	daily	28	table	english	paste and copy text	single station	no	not available

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CYPRUS	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	19.11.03	water level	current year	mean	hourly	1	graph + table	english	on request	single station	on request	available
CZECH REP	Czech Hydrometeorological Institute	http://www.chmi.cz	24.11.03	water level	actual day	mean	daily	28	table	national language	paste and copy text	single station	no	not available
FINLAND	Finnish Environment Institute	http://www.vyh.fi/eng/environ/monitor/hydro/qflow/qflow.htm	24.11.03	river discharge	current year	mean	daily	58	hydrograph	english	text picture	single station	no	not available
FINLAND	Finnish Environment Institute	http://www.vyh.fi/eng/environ/monitor/hydro/qflow/qflow.htm	24.11.03	water level	current year	mean	daily	115	hydrograph	english	text picture	single station	no	not available
FRANCE	Diren Lorraine	http://hydro.rnde.tm.fr	24.11.03	river discharge	current year	mean	daily	215	graph + table	french	paste and copy text	single station	no	not available
FRANCE	Diren Lorraine	http://www.environnement.gouv.fr/lorraine/	24.11.03	water level	last week	mean	daily	55	graph + table	french	text picture	single station	no	not available
Country	Institution	URL	Last visit	Kind of Data	Type of Data	Form of Data	Resolution	Number of Stations	Display	Language	Access	available by	Download	Coordinates
GERMANY	Wasser- und Schifffahrtsverwaltung des Bundes	http://www.elwis.bafg.de/	24.11.03	water level	last week	instant	hourly	135	graph + table	national language	paste and copy text	single station	no	not available
GERMANY	Bayerisches Landesamt für Wasserwirtschaft	http://www.bayern.de/lfw/hnd/	24.11.03	water level	actual day	instant	hourly	400	graph + table	national language	paste and copy text	single station	no	not available
GERMANY	Hessisches Landesamt für Umwelt und Geologie	http://www.hlug.de/medien/wasser/pg_was_dur.htm	24.11.03	water level	actual day	instant	hourly	77	table	national language	paste and copy text	single station	no	not available
GERMANY	Landesanstalt für Umweltschutz Baden-Württemberg	http://www.lfu.baden-wuerttemberg.de/lfu/hvz/	24.11.03	water level	actual day	instant	hourly	178	table	national language	paste and copy text	single station	no	not available
GERMANY	LandesUmweltAmt Nordrhein-Westfalen	http://193.159.218.47/LUA/wiski/phpwel.htm	24.11.03	water level	last month	mean	daily	125	graph + table	national language	paste and copy text	single station	no	not available
GERMANY	Ministerium für Umwelt Saarland	http://www.umweltserver.saarland.de/wasser/hwasser.html	24.11.03	water level	last week	mean	daily	27	hydrograph	national language	text picture	single station	no	not available
GUYANA	HYDROMETEOROLOGICAL SERVICE	http://www.agrinetguyana.org.gy/hydromet/index.htm	24.11.03	water level	actual day	instant	daily	1	table	english	paste and copy text	single station	no	not available
HUNGARY	NATIONAL HYDROLOGICAL FORECASTING SERVICE	http://www.datanet.hu/hydroinfo/	24.11.03	water level	actual day	instant	daily	115	table	english	paste and copy text	single station	no	not available
ICELAND	ORKUSTOFNUN National Energy Authority	http://www.os.is/english/hydro.html	24.11.03	water level	actual day			30		english		single station	no	not available

Annex 1 List of near real time river stage and/or discharge providing online resources

Country	Institution	URL	Last visit	Kind of Data	Type of Data	Form of Data	Resolution	Number of Stations	Display	Language	Access	available by	Download	Coordinates
ITALY	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	19.11.03	water level	current year	mean	hourly	1	graph + table	english	on request	single station	on request	available
JAPAN	Water Information System MLIT	http://www1.river.go.jp/	24.11.03	water level				0		national language				
JORDAN	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	19.11.03	water level	current year	mean	hourly	1	graph + table	english	on request	single station	on request	available
LAO PEOPLE'S DEM REP	Mekong River Commission	http://www.mrcmekong.org/	19.11.03	river discharge	last week	mean	daily	11	graph + table	english	paste and copy text	single station	yes	not available
LAO PEOPLE'S DEM REP	Mekong River Commission	http://www.mrcmekong.org/	19.11.03	water level	last week	mean	daily	23	graph + table	english	paste and copy text	single station	yes	not available
LESOTHO	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	5	graph + table	english	paste and copy text	single station	on request	not available
MACEDONIA	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	19.11.03	water level	current year	mean	hourly	1	graph + table	english	on request	single station	on request	available
MALAWI	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	5	graph + table	english	paste and copy text	single station	on request	not available
MALI	AOCHYCOS	http://aochycos.ird.ne/	19.11.03	river discharge	current year	mean	daily	1	hydrograph	english	paste and copy text	single station	no	available
MALTA	MEDHYCOS	http://medhycos.mpl.ird.fr:8080/newinv/newinv.html	19.11.03	water level	current year	mean	hourly	2	graph + table	english	on request	single station	on request	available
MOZAMBIQUE	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	3	graph + table	english	paste and copy text	single station	on request	not available
NAMIBIA	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	5	graph + table	english	paste and copy text	single station	on request	not available
NIGER	AOCHYCOS	http://aochycos.ird.ne/	19.11.03	river discharge	current year	mean	daily	2	hydrograph	english	paste and copy text	single station	no	available
NORWAY	Norwegian Water Resources and Energy Directorate	http://www.nve.no	24.11.03	river discharge				750		english	password		password	
NORWAY	Norwegian Water Resources and Energy Directorate	http://www.nve.no	24.11.03	water level				900		english	password		password	
PANAMA	Gerencia de Hidrometeorología y Estudios de ETESA	http://www.hidromet.com.pa/	24.11.03	water level	current year	mean	daily	2	hydrograph	national language	text picture	single station	no	available

Annex 1 List of near real time river stage and/or discharge providing online resources

Country	Institution	URL	Last visit	Kind of Data	Type of Data	Form of Data	Resolution	Number of Stations	Display	Language	Access	available by	Download	Coordinates
PERU	Servicio Nacional de Meteorologia eHaidrologia	http://www.senamhi.gob.pe/hidro/cuencas.htm	24.11.03	river discharge	current year	mean	daily	16	hydrograph	national language	text picture	single station	no	available
POLAND	Institute of Meteorology and Water Management	http://www.imgw.pl/wl/internet/hydro/biuletyn.jsp	24.11.03	water level	last week	mean	daily	75	table	national language	paste and copy text	single station	no	not available
SLOVAKIA	Slovensky hydrometeorologicky ustav	http://www.shmu.sk/hips/index.html	24.11.03	river discharge	actual day	mean	daily	79	table	national language	paste and copy text	single station	no	not available
SLOVAKIA	Slovensky hydrometeorologicky ustav	http://www.shmu.sk/hips/index.html	24.11.03	water level	actual day	mean	daily	79	table	national language	paste and copy text	single station	no	not available
SLOVENIA	Environmental Agency of Slovenia	http://www.rzs-hm.si/lang.en/podatki/stanje_voda.html	24.11.03	water level	actual day	mean	daily	25	table	english	paste and copy text	single station	no	not available
SLOVENIA	Environmental Agency of Slovenia	http://www.rzs-hm.si/lang.en/podatki/stanje_voda.html	24.11.03	water level	actual day	instant	contin uously	16	table	english	paste and copy text	single station	no	not available
SOUTH AFRICA	Department of Water Affairs & Forestry	http://www.dwaf.gov.za/Hydrology/	24.11.03	river discharge	last week	instant	daily	160	graph + table	english	paste and copy text	single station	no	not available
SOUTH AFRICA	Department of Water Affairs & Forestry	http://www.dwaf.gov.za/Hydrology	24.11.03	water level	last week	instant	daily	160	graph + table	english	paste and copy text	single station	no	not available
SOUTH AFRICA	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	55	graph + table	english	paste and copy text	single station	on request	not available
SWAZILAND	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	4	graph + table	english	paste and copy text	single station	on request	not available
TANZANIA	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	5	graph + table	english	paste and copy text	single station	on request	not available
THAILAND	Mekong River Commission	http://www.mrcmekong.org/	19.11.03	river discharge	last week	mean	daily	11	graph + table	english	paste and copy text	single station	yes	not available
THAILAND	Mekong River Commission	http://www.mrcmekong.org/	19.11.03	water level	last week	mean	daily	23	graph + table	english	paste and copy text	single station	yes	not available
UNITED STATES	US Geological Survey	http://water.usgs.gov/realtime.html	24.11.03	river discharge	actual day	instant	contin uously	7173	graph + table	english	paste and copy text	single station	yes	not available
UNITED STATES	US Geological Survey	http://water.usgs.gov/realtime.html	24.11.03	water level	actual day	instant	contin uously	7173	graph + table	english	paste and copy text	single station	yes	not available
VIETNAM	Mekong River Commission	http://www.mrcmekong.org/	19.11.03	river discharge	last week	mean	daily	11	graph + table	english	paste and copy text	single station	yes	not available
VIETNAM	Mekong River Commission	http://www.mrcmekong.org/	19.11.03	water level	last week	mean	daily	23	graph + table	english	paste and copy text	single station	yes	not available
ZAMBIA	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	5	graph + table	english	paste and copy text	single station	on request	not available

Annex 1 List of near real time river stage and/or discharge providing online resources

ZIMBABWE	SADCHYCOS	http://www-sadchyco.pwv.gov.za/	19.11.03	water level	actual day	instant	daily	4	graph + table	english	paste and copy text	single station	on request	not available

Selection options for the individual columns:

river discharge	actual day	mean	contin ously		hydrograph	english	display only	single station	yes	available
water level	last week	instant	hourly		table	french	text piture	river basin	no	not available
metadata	last month		daily		Graph + table	spanish	past and copy text	country	on request	
contatcs	current year				station map	portuguese	on request			
						national language	password			
							database			