

## Environmental Data Management with the River Basin Information System (RBIS)

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### Abstract

The pressure on environmental systems is increasing worldwide due to population growth and the consequences of climate change. Adaptable tools and methods are needed to elaborate information, develop understanding and strategies for sustainable use and management of environmental systems. Such tools should assist scientists, natural resource managers and decision makers in their work by providing (1) sufficient information about relevant drivers, attributes and factors from measured data, (2) tools and methods for user friendly access and integrated analyses of such data, i.e. environmental information systems (EIS), and (3) tools for estimating additional information not available as measurements, i.e. environmental simulation models. In addition, a seamless and preferably standardized exchange of data between EIS and integrated assessment tools such as simulation models is gaining increasing importance as the amount of available environmental information is growing together with the complexity of current environmental challenges.

The research at the Department of Geoinformatics, Hydrology and Modelling at the Friedrich Schiller University of Jena is reflecting the needs described above with the development of a number of software tools. They provide services and assistance for specific spatio-temporal related environmental problems emerging from integrated research projects. In general, all developed tools (1) use open source software wherever possible to be cost effective, (2) are provided as open source software to others and (3) are highly flexible and adaptable to ensure usability for a wide range of environmental problems.

In this paper we briefly present the River Basin Information System (RBIS) – a web-based information management system with a focus on time series and geospatial data. It provides user friendly interfaces for data input and output, powerful visualization components and an adaptable set of functions for data analysis, data management and data enrichment. Sample applications from various research projects are used to illustrate that RBIS is an appropriate platform to meet the demands for collaborative and integrated data management.

**Keywords:** Environmental Information Systems, time series management, meta-information catalogue

### 1 Introduction

Integrated environmental resources research carried out by interdisciplinary research groups requires a comprehensive and holistic system analysis and process understanding (FLÜGEL 2007). In turn, it relies on powerful and effective data management. It also depends on information sharing strategies based on best available knowledge to support researchers and decision makers. The literature review reveals that there are numerous attempts to organize and coordinate national, regional, and global geo-spatial data. Nevertheless, it can be stated that integrating complex information such as geodata, time series and meta-information together with statistical analysis and mapping capabilities in a fully integrated way is still challenging (PCGIAP 1998, BASSOLET 2000, WILLIAMSON ET AL. 2003, MANSOURIAN ET AL. 2006).

Many existing data management systems are web-based, where users are able to search, locate and access the provided data sets. Usually, a catalogue service is being implemented to handle search requests providing information about available data sets and how they can be accessed. Technically, data access is then granted through HTTP by using web services like the Open Geospatial Consortium's (OGC), Web Feature Service (WFS), Web Coverage Service (WCS) for geodata or Sensor Web Enablement (SWE) Services for time series data (<http://www.opengeospatial.org/standards>). From a project management perspective, a deficit of such approaches is that users are not able to easily integrate own data, to alter existing data sets or to manage associated meta-information. This is rarely a problem of missing features in available standards, but a lack of support for these functions on the client's side. Regarding the data management design, many of these systems also lack a fine-grained user permission management (e.g. write-permission to only a subset of available data) or map-based user interfaces, like map-based search functions and model-specific interfaces. Often such systems show little flexibility for implementing user-required extensions and applications. On the other hand, non-web-based geodata information systems (e.g. the Chinese Cryospheric Information System, LI ET AL. 2003) are usually stand-alone solutions which do not support multi-client, distributed applications.

The *River Basin Information System* (RBIS, FLÜGEL 2007) developed at the Department of Geoinformatics, Hydrology and Modelling of the University of Jena addresses the abovementioned deficits. This modular-

structured application consists of (i) a comprehensive and spatially enabled relational database and (ii) an application server providing a web-based user interface for easy data access. The common layout of RBIS follows a standard 3-tier architecture design (figure 1) using the *PostgreSQL* DBMS (<http://www.postgresql.org>) as a storage engine.

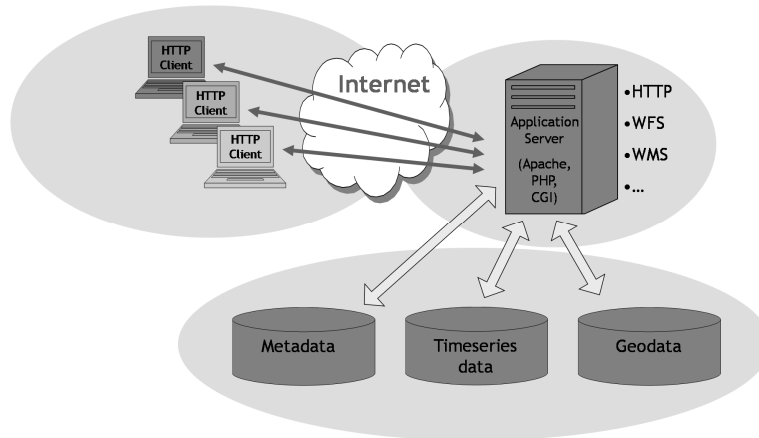


Fig. 1: RBIS technical layout

The RBIS is used in many projects at the Department of Geoinformatics, Hydrology and Modelling of the University of Jena. Examples are the EU-Project BRAHMATWINN (twinning European and South Asian river basins to enhance capacity and implement adaptive integrated water resources management approaches) ([www.brahmatwinn.uni-jena.de](http://www.brahmatwinn.uni-jena.de)) and the BMBF-project ILMS (Integrated Landscape Management System) (<http://ilms.uni-jena.de>).

## 2 Software architecture

As a platform for geodata storage and visualization, the MapServer (<http://www.mapserver.org>) and PostGIS (<http://postgis.refractor.net>) software packages are used. In order to increase the ease of use, some modifications have been applied to the MapServer, e.g. a web-based map editor was added. The components (figure 4) were developed from scratch using available software libraries whenever possible. As a web stack, a standard Linux environment with Apache web server, PHP and PostgreSQL/PostGIS (LAPP) was used. The whole system is built based on open source software, ensuring a cost-effective deployment and operation.

Data is stored within database tables where possible and in the file system otherwise (e.g. raw data). According to the different application components, three different databases (for geodata, time series data and meta-information) are used. This differentiation simplifies the system's administration and opens an opportunity for a distributed deployment.

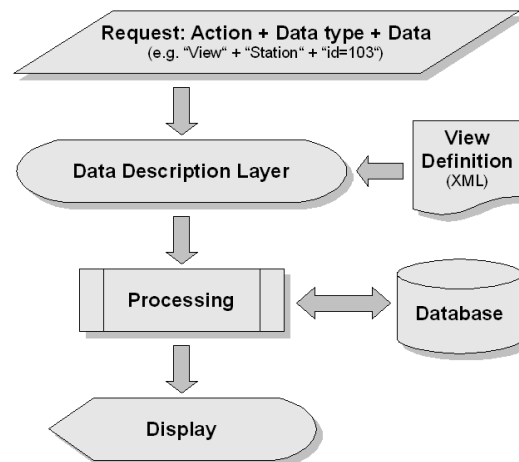


Fig. 2: RBIS information access via data description layer

Since RBIS is accessible via the web and designed for distributed access by users with different levels of access authorization, a flexible and powerful permission management was an important precondition for its acceptance and trustful use. This is achieved by granting access rights to single users and user groups based on:

1. Data types, e.g. access to geodata only,
2. Dataset ownership, e.g. write access to a dataset only for its creator,
3. Dataset location, e.g. access to stations whose position are within some defined spatial vicinity, i.e. a polygon,
4. Dataset properties, e.g. access to time series data which use limitation attribute is set to 'public'.

In addition to the permission management, transparency is accomplished by means of a comprehensive access logging mechanism which is responsible for recording write access to all data.

Due to its flexible and modular database and application design, RBIS can easily be tailored to meet emerging demands for new data types and relationships between them. This is achieved by a description layer in the RBIS software that takes care of read/write access to database contents. A XML document describes database relations and attributes that define a certain data type, e.g. measuring stations. The XML document is then evaluated by RBIS in order to create SQL statements and user interfaces needed to perform different actions on the data, e.g. search, browse, edit, add or delete measuring station datasets (figure 2).

Taking benefits from this approach, all actions have to be implemented only once and can be used to access all kinds of RBIS data. New data types can easily be added by (i) adopting the database design (e.g. by adding new relations and attributes), and (ii) defining how RBIS shall access these data by means of a XML document.

According to the modular database and application design there are only few simple steps necessary to add a new data type to RBIS. At first a database model has to be designed, which describes the new data type and the connections to existing relations e.g. to the ISO 19115 Responsible Party relation (figure 3). The second step is to add the new tables and relations to the database. The final step is to create or modify one or more XML documents to describe the database relations and attributes. Here you also define the field description and order of the visible attributes in the user interface. There is no need to edit any source code.

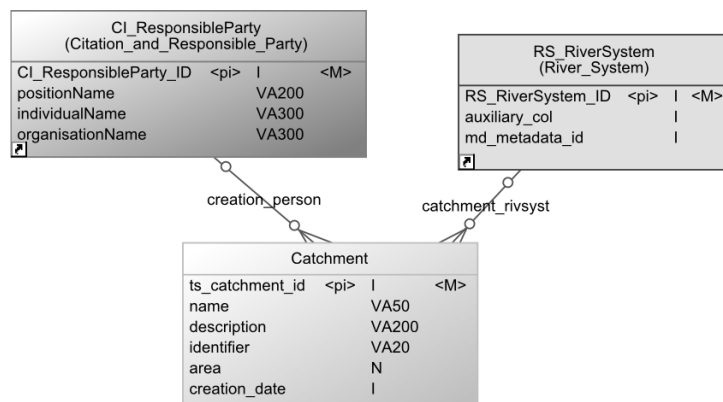


Fig. 3: Part of the database model of the data type catchment

### 3 Meta-information

An important aim during the RBIS development was the description of all data stored through comprehensive meta-information. As a starting point, the ISO 19115-1 metadata standard for geodata (ISO 2003) was used to describe all geodata stored. Later the datamodel was extended by the ISO 19115-2 extension for imagery and gridded data (ISO 2009). To provide information about other data types like measuring stations, time series data or binary-formatted documents the ISO 19115 data model was used where possible and extended where necessary. As an example, the ISO 19115 Responsible Party relation is used to describe both people and organizations that are in charge of certain geodata and those who are responsible for maintaining measuring stations. On the other hand, such stations can be further described by additional information e.g. regarding the parameters being measured or the year of establishment or closing.

Metadata management is handled by the RBISmeta software component which associates meta-information datasets to the datasets of other components. Its interaction with other parts of RBIS is sketched in figure 4.

The RBISmeta component provides an overview for each data type by displaying selected attributes of each dataset (see figure 6). Each column of the overviews can be sorted in descending and in ascending order. Furthermore the user can decide how many entries he would like to see on each page.

The detailed view of each dataset shows all available attributes and linkages to other datasets. All information stored via RBISmeta is searchable. There are two dynamically generated search forms. With the first one the user can enter an arbitrary text in a free text field and search for all datasets containing this text. The other one provides as many selection lists as possible containing only the used entries of an attribute.

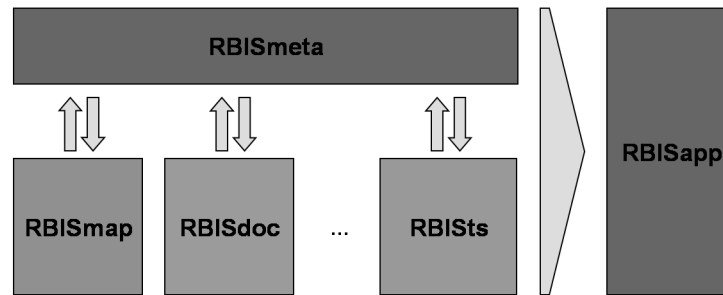


Fig. 4: Interactions of RBIS software components

The workflow of the creation of new datasets has been designed and implemented in order to support and reduce the workload of the user. The input fields are dynamically created according to their data type and length (figure 5). For example short text fields will be presented as normal text fields, but long text fields (>100 characters) will be generated as a text area field. Another example is date input fields. These fields are extended with a calendar function. To guarantee a system wide consistency RBIS provides a large pool of predefined selection list entries. Whenever it is possible selection lists are presented to the user. These lists can include whole categories or parts of them or lists of other stored datasets in RBIS. Examples are lists with units of measurement, station types or countries (full list or a project dependent selection). In addition all mandatory fields are highlighted with red color. All input data is checked before sending it to the database. If any error occurs, all fields filled in incorrectly will appear orange-colored. It is also possible to edit stored datasets, if the user has the required permission for creating or deleting datasets. All datasets can be extended by any type of document; for example pictures of a station or the originally formatted data of a time series.

Overview	
Name	<input type="text"/>
Description	<input type="text"/>
Identifier	<input type="text"/>
Area	<input type="text"/>
River System	<input type="text"/>
Creation date	<input type="text"/>
Creator of dataset	<input type="text"/>

Fig. 5: Part of the form to insert a new catchment dataset

#### 4 Time series management

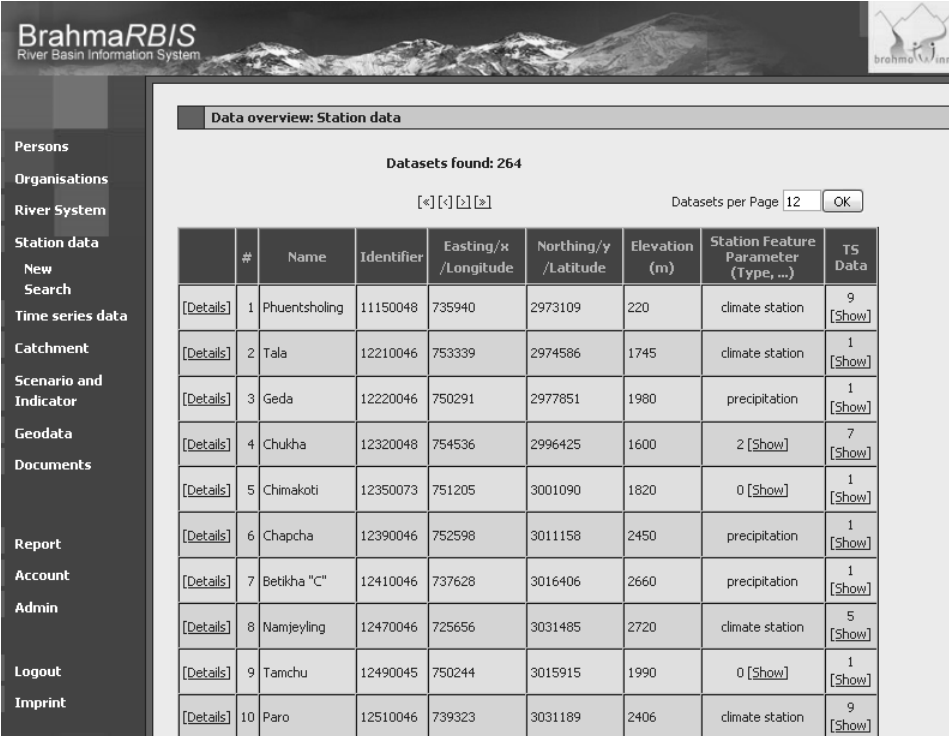
The RBISSts functions for the management of time series data have been designed with special focus on the demands of environmental models. Besides functions for uploading, visualizing and downloading, the following features regarding meta-information (e.g. about the associated station) and the time series itself are provided:

1. Data gap analysis of uploaded data and their detailed description,
2. spatial time series data analysis and data visualization,
3. gap filling toolbox with various algorithms for reconstructing missing data,
4. Aggregation methods for creating various temporal resolutions.

The following sections will describe the concept used to store time series data and their metadata in RBIS, how to upload data, functions to search and view time series data, gap filling processes and different ways to export and access stored time series data.

## 4.1 Storage of time series data and metadata

Time series data are always measured or simulated at a certain spatial position. In RBISs this point is a station, which can be either a real station (for e.g. precipitation and/or gauging station) or a virtual station, if data is simulated. Referring to this concept every station has its own metadata dataset consisting at least of the coordinates, spatial reference system and a name. Additionally some more detailed information can be stored. One is the identifier, which is used in the original measuring network to identify the station. Also the status of the station e.g. working or closed can be added. The river system, where the station belongs to, elevation, country, responsible person or organization as well as year of establishment and closing are also possible information belonging to a station.



**BrahmaRBIS**  
River Basin Information System

**Data overview: Station data**

Datasets found: 264

[\*] [◀] [▶] [x]

Datasets per Page: 12 OK

	#	Name	Identifier	Easting/x /Longitude	Northing/y /Latitude	Elevation (m)	Station Feature Parameter (Type, ...)	TS Data
[Details]	1	Phuentsholing	11150048	735940	2973109	220	climate station	9 [Show]
[Details]	2	Tala	12210046	753339	2974586	1745	climate station	1 [Show]
[Details]	3	Geda	12220046	750291	2977851	1980	precipitation	1 [Show]
[Details]	4	Chukha	12320048	754536	2996425	1600	2 [Show]	7 [Show]
[Details]	5	Chimakoti	12350073	751205	3001090	1820	0 [Show]	1 [Show]
[Details]	6	Chapcha	12390046	752598	3011158	2450	precipitation	1 [Show]
[Details]	7	Betikha "C"	12410046	737628	3016406	2660	precipitation	1 [Show]
[Details]	8	Namjeyling	12470046	725656	3031485	2720	climate station	5 [Show]
[Details]	9	Tamchu	12490045	750244	3015915	1990	0 [Show]	1 [Show]
[Details]	10	Paro	12510046	739323	3031189	2406	climate station	9 [Show]

Fig. 6: Overview of station datasets in the BrahmaRBIS. The last column shows the available time series datasets at each station.

Time series always belong to one station, but every station can be connected with an unlimited amount of different time series with different parameters (figure 6). Time series data itself can be stored with only one parameter or with a list of values of different parameters at the same point in time.

## 4.2 Upload of time series data

To upload time series data it is required to create a metadata dataset, which at least includes a name, the origin of the data, the station, where the data was measured, and the name of the person who created the metadata dataset. In addition it is possible to give a short dataset description and details about data quality. Information characterizing the data itself, like start date and end date, will be set automatically after uploading time series data.

The time series data has to be formatted in a certain way, which can be interpreted by RBIS. It is possible to upload data with one or more values per time step. The file format can be text or CSV. To upload data the user has to specify some important details according to the used date and file format, time step, missing value and the parameter type of the values together with their unit. Whenever it is possible there are extensive and extendible selection lists available to support a consistent data description (upload form: figure 7).

During the upload process the data is analysed and checked against various rules. One of them is the ascending order of dates and the correspondence of given and specified date order. It also includes the analysing of data gaps. If the upload process is finished successfully, all data is stored in the database and the metadata dataset is extended by information about data gaps and time series dataset describing details.

RBIS also provides functions in order to automate the upload process, which is containing the creation of stations, time series data metadata, the conversion of input data into the required RBIS format and the import of the time series data itself. For this reason it is easy to import a large amount of a time series data with little effort.

Upload timeseries data	
Dataset title:	Guwahati Humidity
Choose a predefined template:	<input type="text"/> ?
Specify number of value columns:	<input type="text"/>
1. Select type of parameter:	<input checked="" type="radio"/> Physical parameter <input type="radio"/> Quality parameter
Upload this file:	<input type="text"/> <input type="button" value="Durchsuchen..."/>
Specify file format:	<input checked="" type="radio"/> values separated by tab (*.txt) <input type="radio"/> values separated by ; (*.csv)
Specify date format:	<input checked="" type="radio"/> [year/month/day] <input type="radio"/> [day/month/year] <input type="radio"/> [month/day/year]
2. Time shift*:	<input type="checkbox"/> use time shift
Comment lines start with:	# <input type="text"/>
Specify values for missing data:	<input type="text"/>
Specify time step:	daily <input type="text"/>
Template name:	<input type="text"/> <input type="button" value="Save as template"/>
3.	<input type="button" value="Send file"/>
* (Date will be shifted to the nearest reference date, which is set by the first date.)	

Fig. 7: Upload form for time series data

### 4.3 Explore and view time series data

The detailed time series data view provides a lot of useful information (figure 8). It is divided into three parts: *overall statistics*, *interval statistics* and *edit*. The overall statistics include the name, which is linked to the metadata dataset, the number of entries with the percentage of real values (values not empty and not default values) for each column, start and end date, time step and the possibility to export the complete dataset as stored in the database (filled date gaps and default values substituted by null value) or the original file.

Time series details																			
<b>Overall statistics and actions</b>																			
Dataset title:	<a href="#">Precipitation Daqapela</a>																		
Number of entries:	5630 (74.12 %)																		
Dataset start date:	1990-01-01 00:00																		
Dataset end date:	2005-05-31 00:00																		
Time step:	daily																		
Export:	<a href="#">[database data]</a> <a href="#">[file]</a>																		
<b>Interval statistics and actions</b>																			
	<table border="1"> <thead> <tr> <th></th> <th>Hour</th> <th>Minute</th> <th>Day</th> <th>Month</th> <th>Year</th> </tr> </thead> <tbody> <tr> <td>Start:</td> <td>00</td> <td>00</td> <td>01</td> <td>01</td> <td>1990</td> </tr> <tr> <td>End:</td> <td>00</td> <td>00</td> <td>31</td> <td>05</td> <td>2005</td> </tr> </tbody> </table>		Hour	Minute	Day	Month	Year	Start:	00	00	01	01	1990	End:	00	00	31	05	2005
	Hour	Minute	Day	Month	Year														
Start:	00	00	01	01	1990														
End:	00	00	31	05	2005														
Time interval/ Columns:	Columns: <input checked="" type="checkbox"/> precipitation (mm)[14574][1][n5T] <input type="button" value="set interval"/>																		
Number of entries:	5630																		
Dataset interval:	1990-01-01 00:00 -- 2005-05-31 00:00																		
Export database data:	<a href="#">[with gaps unfilled]</a>																		
Export aggregated:	<input type="radio"/> monthly <input type="radio"/> yearly <input type="radio"/> hydrolog. year <input checked="" type="radio"/> sum <input type="radio"/> average <input type="checkbox"/> max <input type="checkbox"/> min <input type="button" value="download"/>																		
Show:	<input type="button" value="show plot"/>																		
<b>Edit data</b>																			
Change:	<a href="#">[add data]</a> <a href="#">[delete all data]</a> <a href="#">[extend]</a>																		

Fig. 8: Time series details

In the second part the user can modify the time interval and choose the parameters of interest. Behind every parameter some related functions are linked. If any gaps of the parameter exist, statistical facts about data gaps are shown (sum and number of gaps) which are linked to the detailed view of the gaps. This detailed view shows begin, end and length of every data gap. The data gap filling method used is displayed in addition, if filled data is available. The next link behind the parameter indicates the status of data gaps with its color. If the “T” is colored red, no data gaps are filled. The color blue represents a partly and green completely filled data. The link leads the user to the gap filling toolbox.

The last link behind the parameter, which is always visible, leads the user to the form in which one can explore the time series data more in its spatial context e.g. find the nearest station, which may fit for closing data gaps (figure 9). The user can set up diverse criteria for searching. It is possible to give a limit for the maximum distance, number of stations that shall be included and the temporal extent. Furthermore the minimum and maximum elevation of the stations can be limited and the minimum correlation value between two time series. The correlation between the referencing time series to all other time series with the same parameter and time step can be calculated on demand. The search result can be arranged according to distance or the correlation value and can be visualized in a diagram which shows the available data and data gaps over time.

Station: Kappl-Oberhaus / TS Type: precipitation

Maximum distance (m): 0 and/or number of TS: 5 TS-data between [calendar icon] and [calendar icon]

Elevation (m) between [input] and [input] Rsquared (r<sup>2</sup>)\* > 0 Order by  distance  rsquared  Exclude raw data

Station	Distance (km)	Dataset title	Elevation	r <sup>2</sup> *	TS-Start	TS-End
Kappl-Oberhaus		<a href="#">Kappl-Oberhaus daily precipitation</a>	1500		1999-05-01	2001-12-31
<a href="#">See im Paznaun</a>	6.924	<a href="#">See im Paznaun daily precipitation</a>	1040	0.88	1971-01-01	2001-12-31
<a href="#">Flirsch</a>	9.116	<a href="#">Flirsch daily precipitation</a>	1150	0.83	1990-01-01	2001-12-31
<a href="#">Ischgl/Idal</a>	10.703	<a href="#">Ischgl/Idal</a>	2319	0.16	1990-12-01	2007-04-24
<a href="#">Spiss</a>	12.187	<a href="#">Spiss daily precipitation</a>	1540	0.79	1971-01-01	2001-12-31
<a href="#">meteo33</a>	15.194	<a href="#">Meteo33</a>		0.31	1970-01-01	2003-12-29

Fig. 9: View to analyze and explore time series data

#### 4.4 Gap filling toolbox

Dealing with measured data implies to work with fragmentary data for example having gaps. To analyse long time series or to run a model, it is required to fill these gaps as good as possible. There are many methods for gap filling and therefore it is necessary to store not only the calculated values filling a gap, but also the method which was used to make sure that any data modification is always transparent, reproducible and reversible. The RBISs gap filling toolbox was implemented to meet these requirements.

RBISs provides different gap filling methods. An example is the *inverse distance weighting* method (SHEPARD 1968) to fill data gaps using data from neighbouring stations. This method is very common since every time series is associated with a measuring station and thus has a geographical location. The best suited filling method is selected by a rule-based algorithm whose rules can easily be defined by the user, e.g. inverse distance weighting for temperature data is used if at least 3 stations provide measured data for the time interval and are located in a range of less than 50 km. Other available methods are inverse distance weighting with elevation correction, linear interpolation, linear regression and nearest neighbour. To adjust the rules it is also possible to limit the gap size to use different methods for different gap lengths. For example a simple linear interpolation is used for gaps smaller or equal a gap size of 3 and a linear regression is used for all gaps greater than 3. Furthermore, the correlation coefficient can be used as a limiting factor in a rule.

In addition to the system's methods for gap filling, RBISs also allows the upload of externally created gap data to complete a time series. In all cases, detailed meta-information about the procedure used and all relevant parameters are stored along with the gap data.

## 4.5 Export and access of time series data

The purpose of RBISs is not only the storage and collection of time series data from a project but also to provide the data for analysis outside of RBIS, modelling and simulation. There are two different ways to access the stored data. The first is the direct export of data with several options and second the direct access to the database from a model.

There are some basic export options. The first option is to export the complete dataset as stored in the database or the original file. The data is stored with filled temporal gaps, which implies that all missing time steps are filled with null values and additionally default values are substituted by null values. The second export option allows to define a time interval and a set of parameters of interest. If time series with filled gaps are available, the whole time series or parts of it can be exported with the same options.

The advanced export includes aggregation functions. In dependency of the given time step data can be aggregated to hourly, daily, monthly or yearly values. Yearly values can cover a calendar or a hydrological year. Depending on the requirements, parameter values can be calculated as sum or average value. To get an idea of the range, minimum and maximum values in a time interval can be calculated. To allow a quality inspection of the calculated values, the percentage of the values used in the calculation is always given.

The direct access to the data from a model is exemplarily realized with the coupling of RBIS and the *Jena Adaptable Modelling System* (JAMS), which is also developed by the Department of Geoinformatics at the Friedrich-Schiller-University Jena (KRALISCH ET AL. 2006). JAMS is a modelling framework for the component based development and application of environmental simulation models. It was used to implement a number of process-oriented models mainly for simulating water and solute transport processes. RBIS provides a software wizard that helps selecting the desired parameter, time interval, and temporal resolution, as well as choosing a number of time series from a list of matching ones. The result is a XML-based document containing information in the *JAMS Data Description Language* (JDDL), which can be downloaded and made available to JAMS in order to read the chosen data. From a user's perspective, no additional effort is needed to prepare data, like gap filling, data formatting or checking for correct start and end dates in the case of time series data (KRALISCH ET AL. 2009).

## 5 Geodata management and visualization

Projects dealing with environmental data use data which is related not only to time but also to space. In order to provide a way to manage spatial data and its visualization the RBIS software component *RBISmap* was developed by partners of the Department of Geoinformatics at the Friedrich-Schiller-University Jena. The software component RBISmap also uses open source: the UMN MapServer to create maps and OpenLayers with Ajax techniques for a user friendly display of map data in a web browser (see figure 11).

The following section will describe some key functions of RBISmap from uploading data over displaying data to the linkage between geodata and stations and their metadata.

### 5.1 Uploading data, creation and visualization of maps

Importable data can be categorized according to the following three types: Geodata (vectors and rasters), any user data (attributes) and data that is linked to spatial objects. The following formats can be imported: ESRI Shape file, TIFF and GeoTIFF, CSV and Dbf (dBase format). Depending on the format the upload process differs to meet the special needs. Users have to specify the path of all files belonging to one dataset and a name for the dataset. To reduce the effort in uploading the data can also be imported as an archive (\*.zip, \*.tar, \*.tgz, \*.gz). Like in RBISs a mass import function is also available. A preview is available for all data uploaded in order to help the user in getting an overview of all data stored and during the creation of new layers or maps.

The UMN MapServer needs a Mapfile with certain map elements, layout and contents to generate a map. The Mapfile can be created for example with the help of a text editor. Here RBISmap provides user-optimized HTML forms. The forms consist of three elements: entry fields, pull down menus and links. Each of the Mapfile parameters consists of a help symbol for the MapServer syntax, a number of position, the name (key) of the element, an entry field, a selection field and a checkbox to remove an entry (figure 10).



LAYER				
help	position	key	value	remove
		<b>LAYER</b>	brahmaputra_basin	
⊕	1	NAME	brahmaputra_basin	<input type="checkbox"/>
⊕	2	STATUS	ON	<input type="checkbox"/>
⊕	3	CLASS	brahmaputra_basin	<input type="checkbox"/>
⊕	4	TOLERANCE	0	<input type="checkbox"/>
⊕	5	DATASOURCE	select	<input type="checkbox"/>
⊕	6	PROJECTION		<input type="checkbox"/>
⊕	7	GROUP	boundaries	<input type="checkbox"/>
			select node	<input type="checkbox"/>
				<input type="button" value="save"/>

Fig. 10: Form for editing a Mapfile

Maps are visualized in a user friendly frontend (figure 11) with a lot of functions e.g. zoom in and out, move the map with the mouse, change the order of the displayed layer and decide which layer is visible and view the properties of all geometry objects.

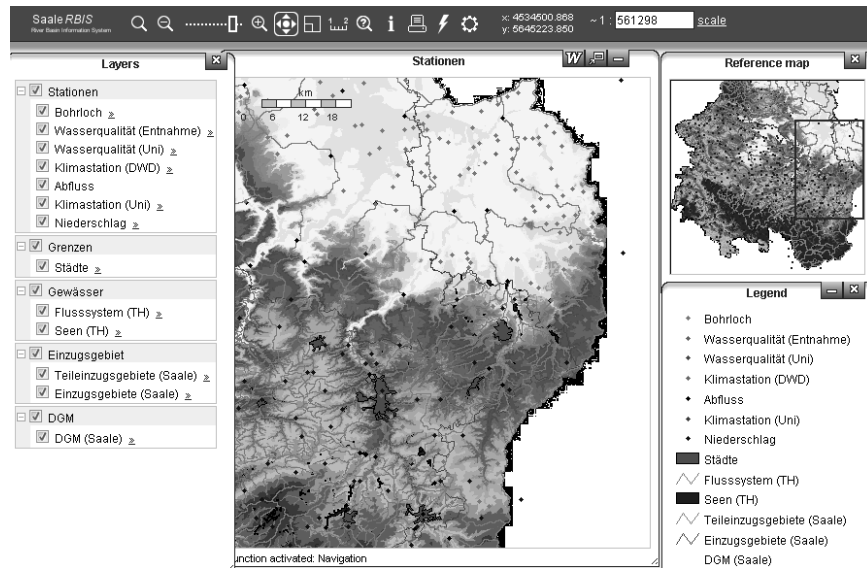


Fig. 10: RBISmap frontend of the SaaleRBIS (related to ILMS) to view maps

## 5.2 Creation and linkage to metadata

Every layer stored in RBISmap can be described by metadata which complies to the ISO 19115 standard. To make sure the user describes every dataset with metadata a layer can only be used in a map, if a metadata dataset has been created. During the creation of metadata all information which can be extracted automatically, e.g. the extent, will be filled in automatically to minimize time and effort. Every layer is linked from metadata to all maps, in which the layer is being used. In the map view every layer is linked to its metadata as well. The linkage allows an easy switching between metadata and different maps.

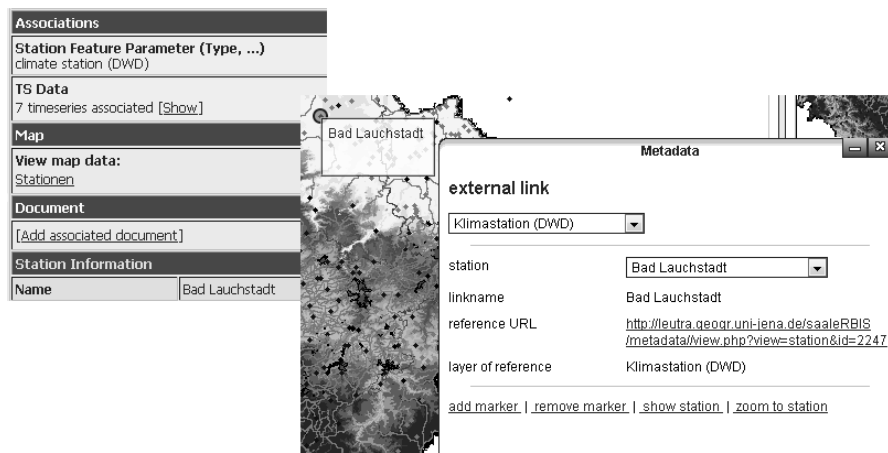


Fig. 11: Exploring time series data

Not only layers can be linked to metadata but also stations (figure 11). Stations as described in section 4.1 are used to spatially relate the stored time series data. To show their spatial relations every station, described by coordinates and reference system, can be visualized in a map. Based on predefined rules the geometry object of a station is placed in one or more different layers of one category, e.g. all precipitation stations. If the description of a station changes the visualization is automatically updated, e.g. the coordinates where filled in wrong or the station type has changed. The predefined rules can be set up freely which allows defining complex conditions for e.g. a layer containing all climate stations with measured precipitation data without gaps between 01.01.1980 and 01.01.2000. All automatically created geometry objects are linked to their original metadata dataset, which means all displayed stations in a map have a link back to their metadata as well as every metadata dataset is linked to a map. Because of this the user can easily search for stations around and switch between the metadata and a map.

## 6 Summary and Conclusion

We have presented an environmental information system as important prerequisites for an integrated assessment of natural systems. We have introduced the River Basin Information System (RBIS) as an application for web-based management of geo-related data with a strong focus on meta-information. In addition, RBIS is especially suitable for managing time series data and provides various functions for analysing and filling data gaps, which usually is an important pre-processing step for environmental model applications.

Future work on RBIS will focus on further enhancing the output of simulation results from JAMS to RBIS. Especially the automated creation of model application descriptions in RBISsim and the output of geodata layers representing simulation results are in the focus of ongoing development. Furthermore new RBIS components for the management of soil related information are under development. Next step will also be adding functions which will enable RBIS to act not only as an information system, but also as a decision support system. It is planned to implement a clearly represented management of projects results like calculated indicator values for different climate scenarios as well as to provide an integrated access to simulated time series data.

Environmental data management systems as introduced in this paper simplify analysis and processing of available information and support researchers, decision makers and stakeholders in making best use of available knowledge. Therefore, we consider it is an essential prerequisite for integrated assessment of environmental systems.

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