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Information Management of Multi-Scale Physical State Varibales in an Interdisciplinary Research Unit

INFORMATION MANAGEMENT OF MULTI-SCALE PHYSICAL STATE VARIBALES IN AN INTERDISCIPLINARY RESEARCH UNIT

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ABSTRACT

Information management is one important and challenging task in engineering projects. The progress in computer simulation techniques, new measurement techniques in field and laboratory as well as the access to mass of data via the Internet requires new information management strategies beyond traditional database solutions. This paper describes the information management in an ongoing research unit dealing with the coupling of flow and deformation processes for modeling the movement of natural slopes. Based on a generalized information modeling approach using sets of tensors an innovative information management system allows the handling, analysis, reporting and archiving of any physical state variable on different time and spatial scale. This leads to an efficient integration/coupling of different models with related information mapping methods as well as information mining approaches for scenario and process identification. .

Keywords: hydroinformatics, Web-based information system

1. INTRODUCTION

1.1 Information from Field, Lab and Simulation

Projects in geo/water related research and engineering are using mass of information originating from field measurements, laboratory experiments and numerical simulations on different time and space scales. The management and the utilization of such information requires suitable information systems to support efficient interdisciplinary and distributed project collaboration as well as the integration of models and data on different scales.

Figure 1: Information from field, laboratory and simulation
(Lindenmaier 2008, Germer 2008, Stadler 2008)

1.2 Research Unit "Natural Slopes"

The interdisciplinary research unit "Großhang – Natural Slopes" deals with the "*Coupling of Flow and Deformation Processes for Modeling the Movement of Natural Slopes*". The research unit is structured in five highly integrated sub-projects. The central sub-project supports the research project with a Web-based information system to manage multi-scale physical state variables and to integrate information from field, lab experiments and numerical simulation.

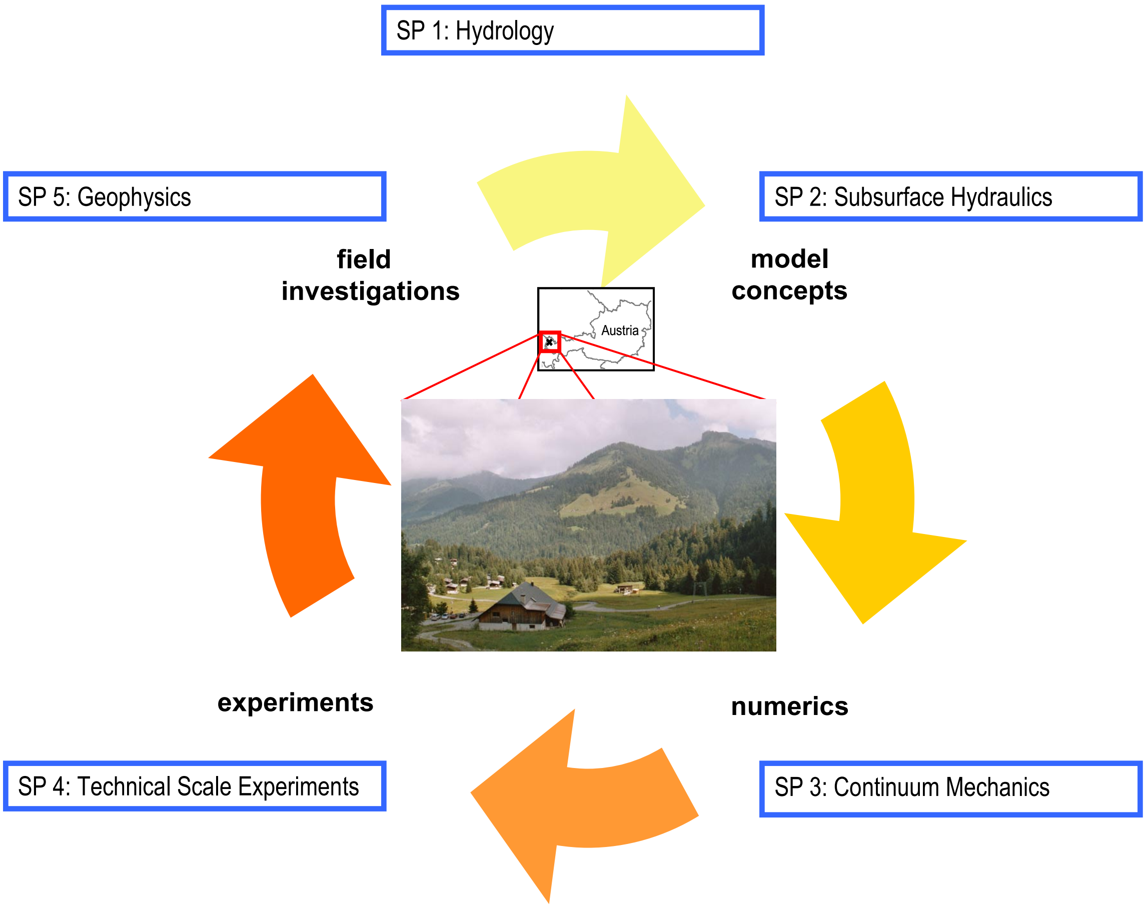

Figure 2: Research unit "Natural Slope" http://www.grosshang.de

1.3 Field Measurements "Heumoes Slope"

The research activities are based on an unique data set for the Heumoes Slope in Ebnit/ Austria. A huge number of heterogeneous data files from different sources have been collected over several years (see Lindenmaier 2008). The data covers hydro-meteorological and geo-hydrological physical state variables on different time scales and spatial distribution. The quantity is still growing due to ongoing permanent measurements, new instruments (e.g. inclinometer in borehole) and additional short period measurements (tracer tests).

2. INFORMATION MANAGEMENT CONCEPT

2.1 Physical State Variables

Key idea of the information management within the project is the generalized information modeling using object-oriented principles. All relevant physical state variables are modeled by tensor classes and managed by sets using the principles of generalization and standardization. Meta data describe all relevant information about data origin such as measurement methods. The tensor classes include all suitable functionality for engineering purposes such as analysis, visualization, reporting and interfacing (Molkenthin 2006).

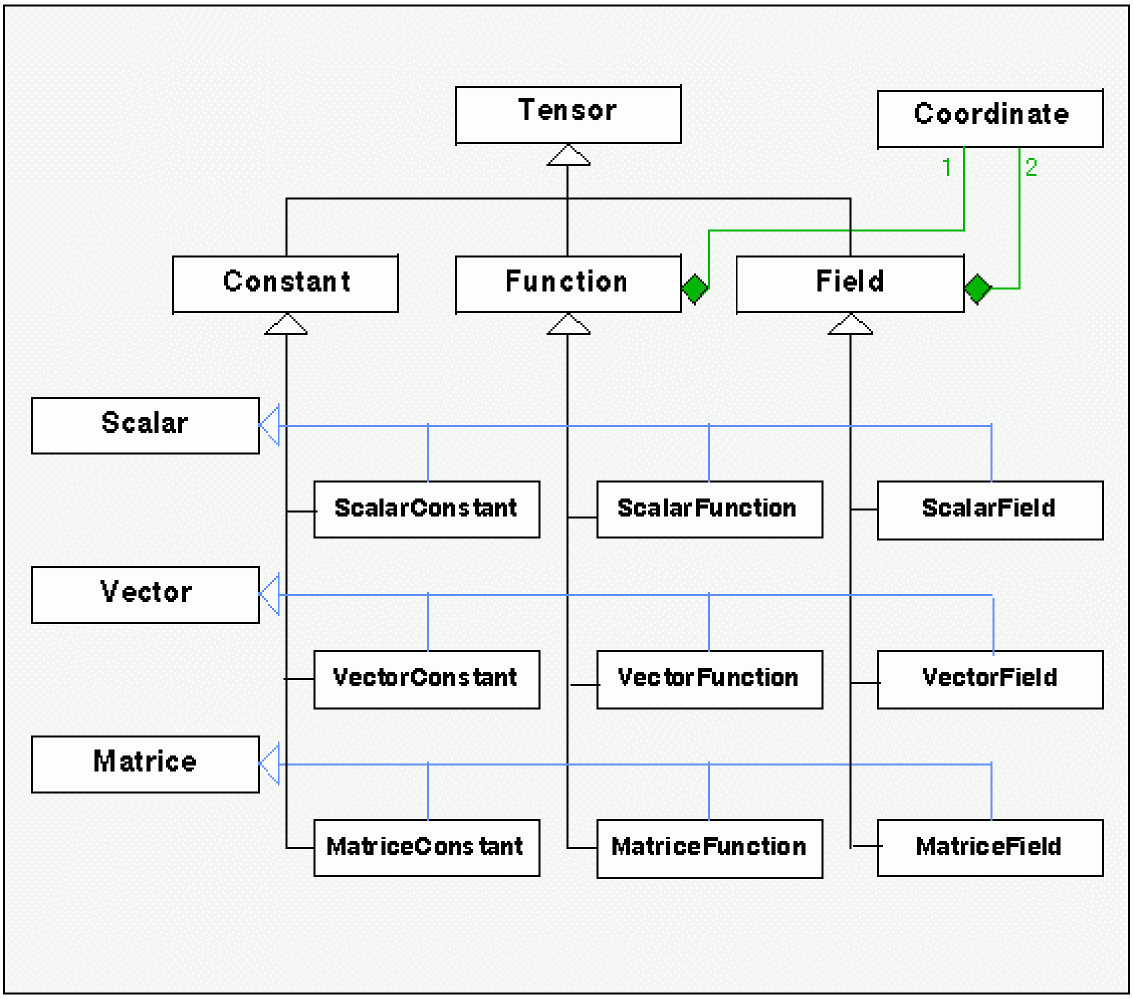

Figure 3: Overview structure of tensor classes

The described approach has been used to develop a flexible information system with the code name Turtle (Molkenthin 2006). The system consists of tools for user interfaces (editor, analysis and visualization), report generator (interactive HTML report), information archiving (XML based), import/export as well as metadata management. Turtle integrates the traditional separated pre- and post-processing, data bases and simulation processors in a holistic but flexible hydroinformatics system. The efficiency of the generalized approach has been demonstrated by several applications, such as the DFG project “Modeling of High-Frequency Internal Waves” at Univ. Stuttgart (Kobus 2006), the EU-Boje in Lake Constance, University of Konstanz, Limnological Institute, a call centre resource management project and the sediment database for rivers in Germany.

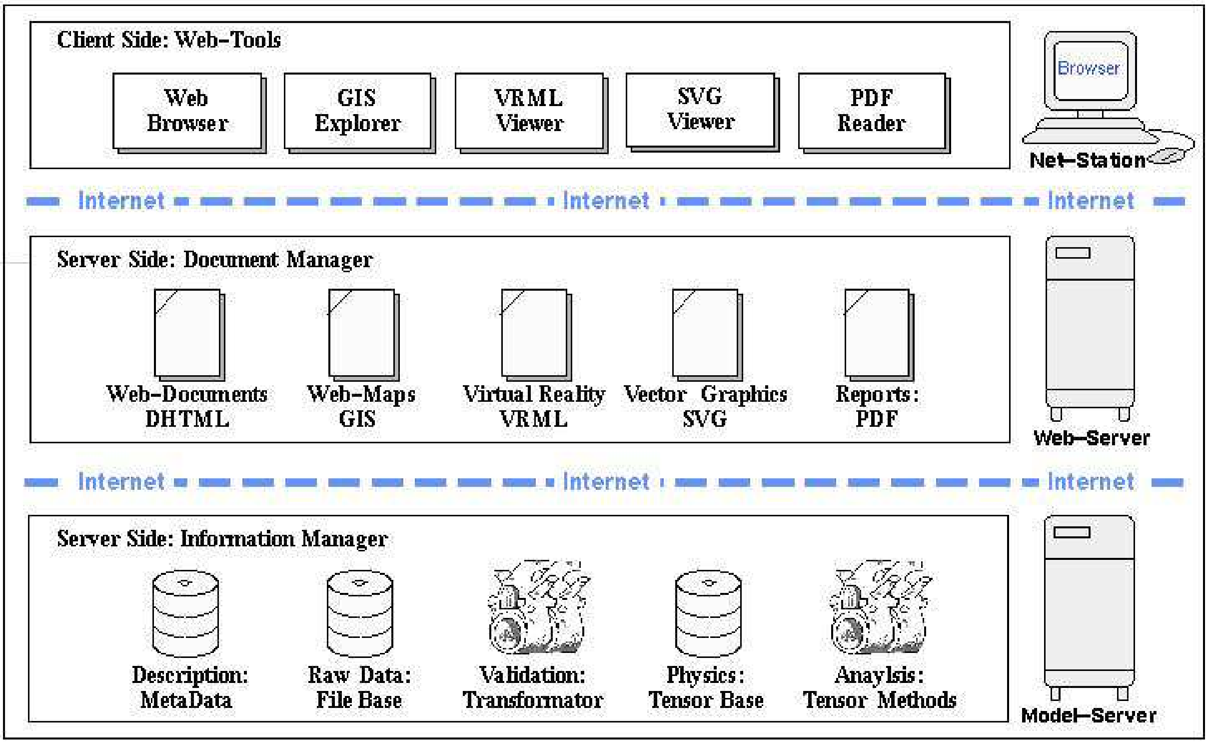

Figure 4: Concept of information system "Turtle"

3. SYSTEM APPLICATION

3.1 Field Measurements: Raw Data Structure

Turtle has been applied for the field measurements at Heumoes Slope, Ebnit/Austria. The raw data of the field measurements are stored in data files, using mainly proprietary ASCII formats depending on the instrument / station configuration and technical equipment. Several permanent and temporal field measurements are available:

- Meteorological and hydrological stations
- Creek measurements
- Tracer measurements
- Borehole measurements

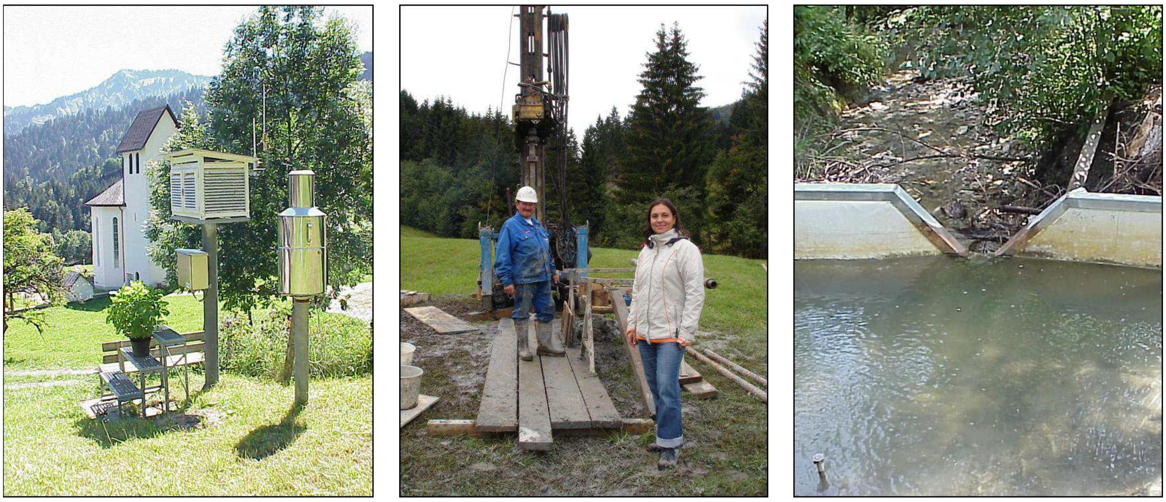
Figure 5: Field measurements: meteorological station, borehole and weir

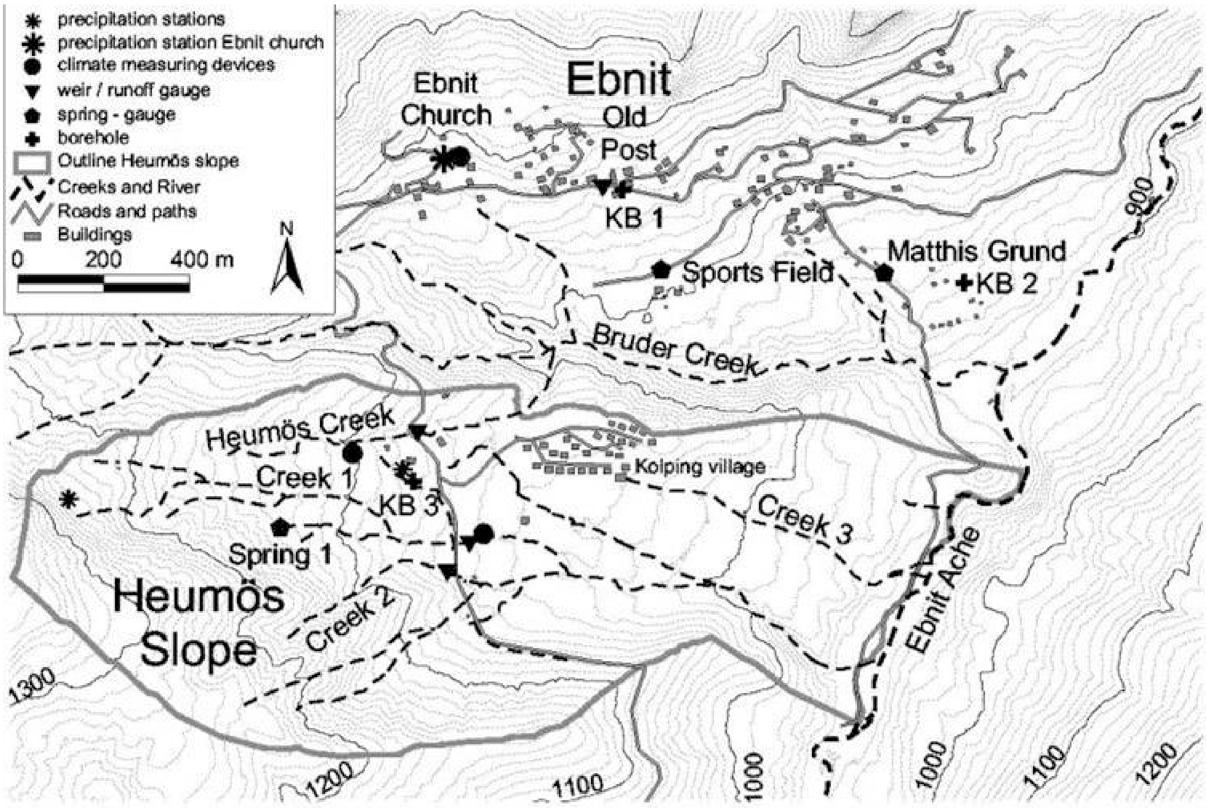

Figure 6: Map field investigations Heumoes Slope (Lindenmaier 2008/2005)

The available data is handled in three steps:

1) Classification by **metadata** including filter and validation rules
2) Integration in the **file base** of Turtle as original raw data
3) Transformation in the **tensor base** of Turtle with flexible time scales

3.2 Metadata: Model, Station, Instrument, Tensor

The performed field measurements are described in a suitable information model and related metadata. All measurements from one source (data service) are combined in one file model structured by stations. Each station consists of several instruments, the instrument itself is linked to one or more measured physical state variables modeled as tensor objects. File model, station, instrument and tensor do have metadata properties to describe all relevant properties, such as location, operation time, tolerance, sampling rate, units, serial number.

3.3 File Base: Raw Data Validation

The raw data are stored in several files with different data formats in the raw data file base. The file base is analyzed in respect to format validation and measurement metadata such as time window, sampling rate, type and unit of the measured physical state variable and measurement gaps. The raw data itself is validated by rules. Examples are value ranges and filter methods. Value ranges define valid ranges of data, such as physically rules (e.g. air humidity between 0% and 100%) or instrument based limitations. Filter methods can be used to define specific operations for specific time windows, such as NaN values for out of operation, or data offset for wind direction instrument shift. Time shift operations are used to transform all data from local measured time zones (CET, CEST or UTC) in one standard time zone (UTC).

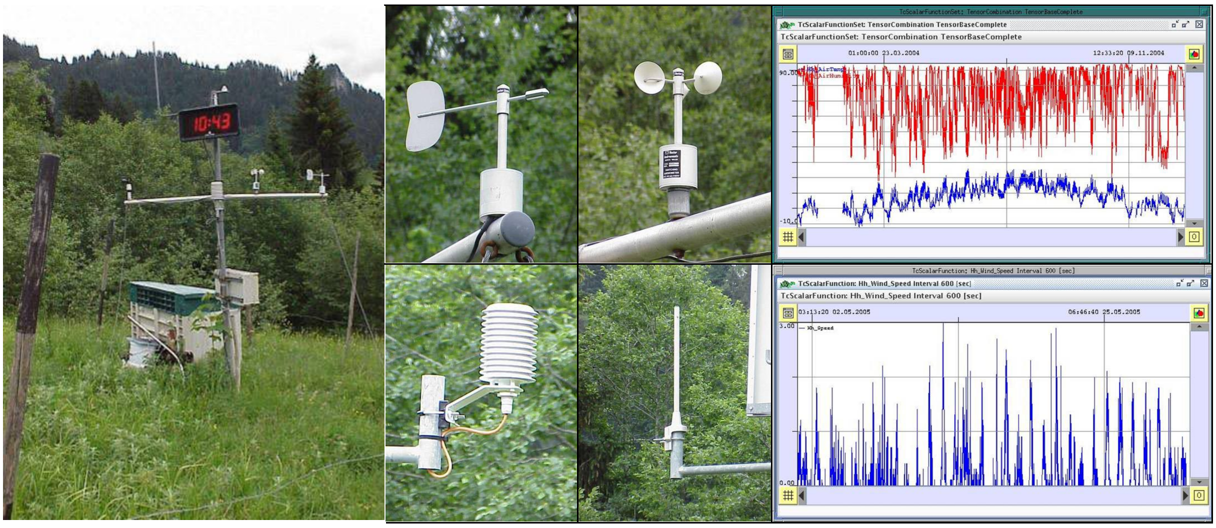

Figure 7: Metadata structure: station, instrument and tensor

3.4 Tensor Base: Time Scales

The raw data are transformed into the tensor base. The tensor base consists of tensors for a predefined project time window (1998-2008) and time scales for all physical state variables. Basic regular time step is 600 sec. Further time scales can be specified, typically time step resolution of 3600 sec (1h), 21600 sec (6h), 86400 sec (1d) and 604800 (7d) are used. The transformation between the time scales is part of the tensor base using typically mean value or sum-up methods. Separated measured state variables can be composed by tensor operations such as wind direction and speed towards wind vector or soil moisture at different depth towards a 2D (time, depth) scalar field.

3.5 Tensor Base: Depending Tensors

The transformation of raw data in the tensor base considers the measured state variables. Further interesting physical state variables can be included as depending tensors. The relationship is again a tensor, which might be time depending. Examples are the API (Antecedent Precipitation Index) function for precipitation or the discharge tensor within creeks. Based on the weir geometry and instrument configuration adequate rating curves can be specified for specific time windows.

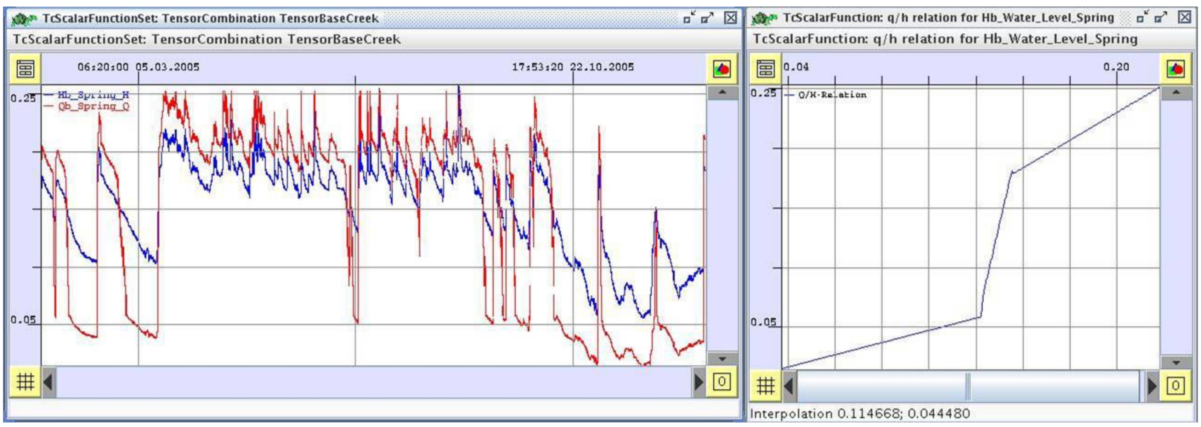

Figure 8: Q/H relationship by rating curve

3.6 Tensor Set Management and Information Mining

The different tensors can be managed and analyzed by tensor sets in a flexible manner. Examples are a tensor set of air related physical state variables or a tensor set of precipitation and water discharge tensors. This flexible set management within the tensor base allows comparing information from different sources (e.g. measurement and simulations) within one tensor set in the same information modeling scheme and on the same approximation level.

Tensor objects combine following the object-oriented approach data and methods of physical state variables. One important group of methods are adapt analysis methods. Theses methods allows an efficient geospatial and time series based information mining within the tensor base on different time scales and for any kind of tensor set. In the ongoing research unit "Natural Slope" this will be used for pattern recognition, signal processing and scenario identification towards a better understanding of the physical processes of the hill slope.

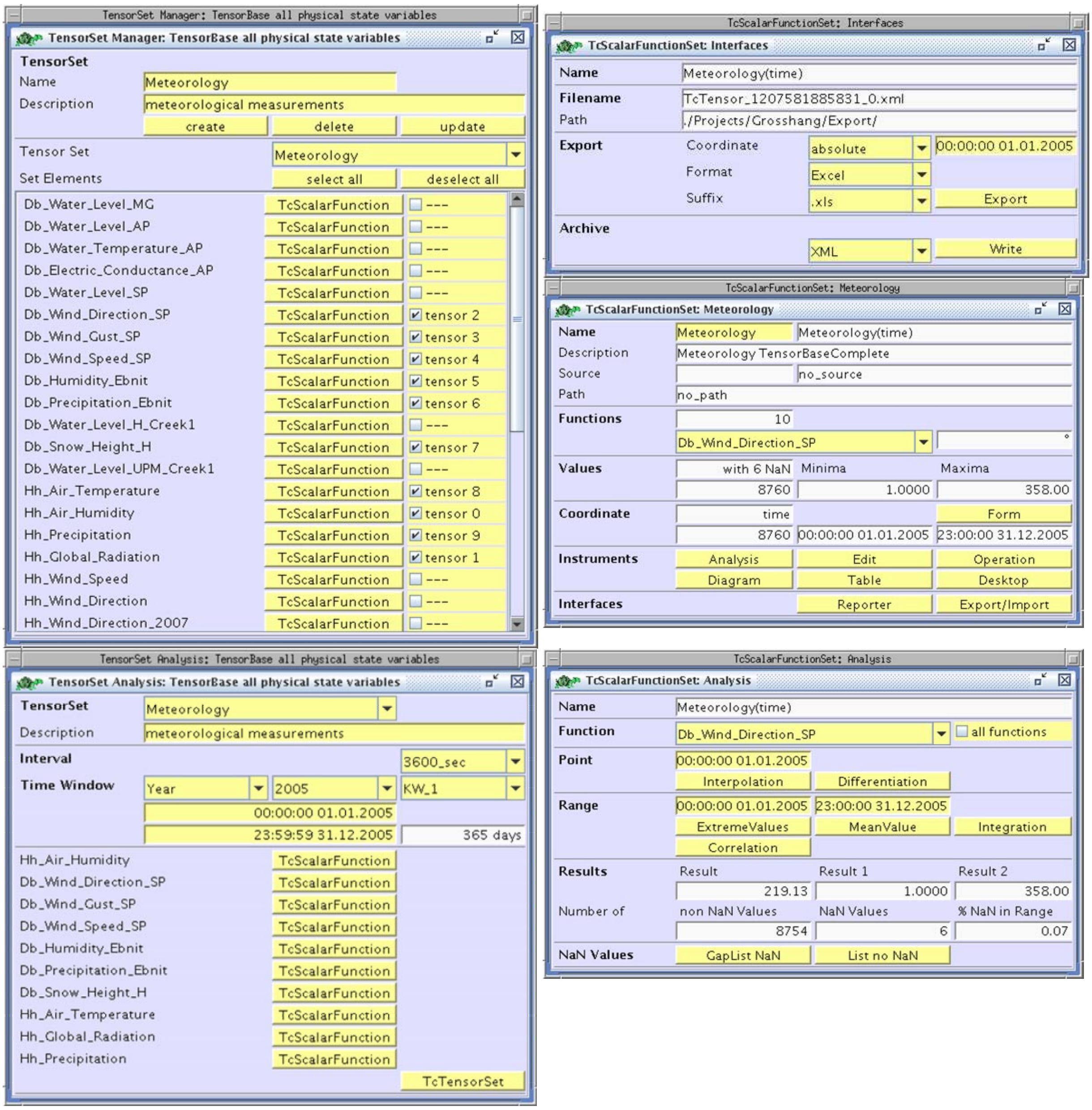

Figure 9: Examples for set management tools and analysis tools

The tensor base of the information system Turtle can be used to couple different software modules. Standard data exchange interfaces can be used to export data by user selection for specific time scale, time window and set combination. Supported data formats are Excel, CSV, MatLab and others (see Figure 9). Turtle is designed for an efficient coupling of different simulation models and information resources using technologies such as XML-RPC and OpenMI. In this way it can be used to manage the information flow and transfer of multi-scale physical state variables within complex modeling environments such as the research unit “Natural Slope”.

The model integration concept is sketched in Figure 10. Turtle will be used as central information base for the integration of the different information sources and modeling systems. Using the internal up- and downscaling methods of tensor objects, information can be mapped for the specific needs of the simulation models. This approach strongly supports the interaction of field investigations, laboratory experiments and numerical modeling.

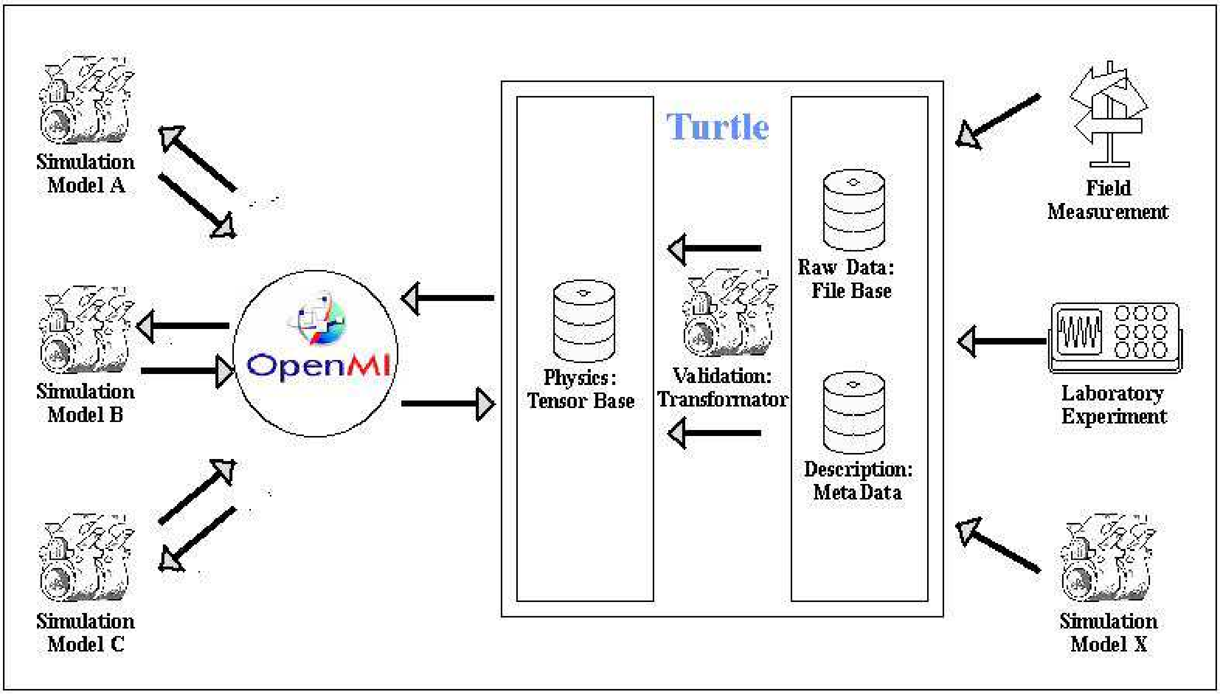

Figure 10: Model integration concept

3.7 Interactive Web Report

The information system generates an interactive Web report with the whole information content of the file base and the tensor base as well as the related metadata. The Web report for the tensor base contains interactive functionality using JavaScript functions similar to modern Web 2.0 / Ajax technology. This interactive functionality allows a flexible navigation through the existing information scheme. All data is represented in tables for specific time windows and time scales, combined with related excel sheets / XML data files for data export. Basic analysis results such as extreme values, mean values and deviations are reported in the Data Viewer. A graphical visualization is implemented by the Image Viewer. The Web Report is a report which does not allow changing any data or information but enables a flexible view and access. This is an important support for Web-based collaborative engineering in larger distributed research projects such as the research unit “Natural Slope”.

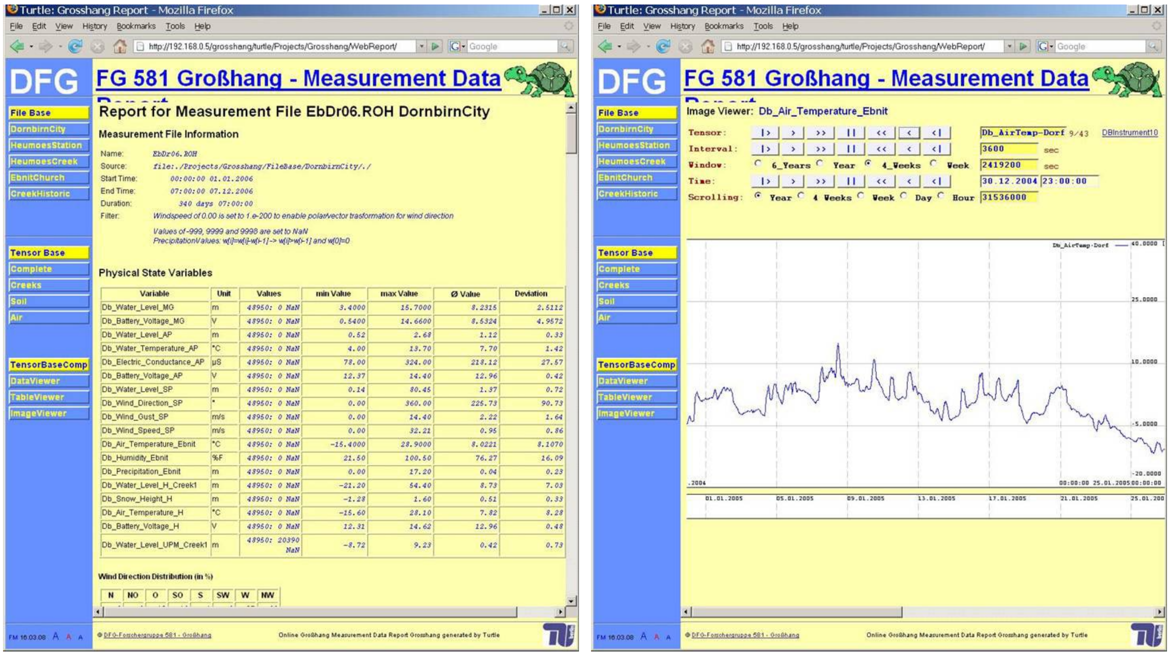

Figure 11: Interactive web report

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