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GLOWA-Danube

INTEGRATIVE TECHNIQUES, SZENARIOS AND STRATEGIES REGARDING GLOBAL CHANGE OF THE WATER CYCLE

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Abstract:
The aims of GLOWA-Danube are the development and validation of the web-based Global Change Decision-Support-System DANUBIA as a platform for integration, the development of integrated modeling approaches based on unified modeling techniques and integrative monitoring using remote sensing. DANUBIA will be used as simulation tool to test future sustainable development alternatives for multinational mountainous watersheds and their forelands, such as the Upper Danube catchment, under Global Change conditions. After the proof of concept in the first project phase, DANUBIA was validated for the years 1995-99 and then applied for a first prototype scenario considering the IPCC trends for the next 100 years. Other activities of the past project year include the initialisation of a moderated stakeholder dialogue, production of a both online and printed Upper Danube Global Change Atlas as a tool for stakeholder negotiations as well as the development of model concepts for the simulation of vehicular traffic flows and wind-induced snow transport to support the project groups with prototypes for the concepts of the deep actor and lateral subproxel processes, respectively.

1. Overall aims of the project

It is the goal of GLOWA-Danube to develop and validate integration techniques, integrated models as well as monitoring methods for the functional catchment type in the alpine foreland of the humid latitudes, and to implement them in the network-based decision support system DANUBIA. DANUBIA includes the essential natural and social science processes which are required for a realistic simulation of water fluxes in mountain-foreland regions. Therefore, it is considering lateral fluxes, upstream/downstram relations, meteorological gradients as well as specific use of sensitive boundary regions; furthermore, it is transferable, i.e. can be applied to the very different catchments of the GLOWA-transect (Mauser 2003). DANUBIA was built up as a prototype in the first project phase and its usabiltiy tested with validation runs which represent the actual state and can thus be compared with measured data. DANUBIA describes the concerned processes spatially distributed and is prepared to explicitely deal with lateral redistribution of water-, energy and matter fluxes as well as migration and cash flow. To implement the coupled model as a basis for DANUBIA new approaches were consequently used which are available from current developments in information technologies. They allow to build new bridges between the participating disciplines and discover new possibilities of integration between them.

Further goal of GLOWA-Danube is to apply DANUBIA exemplarily for the thematical complexes of Global Change of the water cycle for the Upper Danube catchment, i.e. develop related future scenarios and investigate their sustainability. Such scenarios are commonly developed together with the relevant stakeholders within the framework of a moderated dialogue to collect all required experiences for the implementation. The complex scenarios which will be investigated with DANUBIA in the future include, above all, climatic, politic, economic, demographic and technologic deviations from the current state, and they also consider changes in the use and its intensity of land and water resources. In its final release, DANUBIA will be made available as an instrument to all parties who are involved in the management of water resources (politics and administration, planning authorities, non-governmental organisations (NGOs), science and economy, Fig. 1).

During the first project phase, which ended in Feb. 2004, a prototype of DANUBIA was developed for a distributed LINUX cluster computer with 52 nodes using the integrative tools described above. The prototype includes meaningful models from all projects partners describing the sectoral processes and the interfaces between the involved disciplines. The prototype of DANUBIA was not optimized for computing efficiency and was not in all cases using the most sophisticated models for all processes. This prototype of DANUBIA was successfully run as a proof of concept at end of Phase 1 to show the feasibility of the approach (Ludwig et al. 2003). After the first project phase and validation of the DANUBIA prototype the first operational version 1.0 of DANUBIA was released. For this version an automatic delivery system for new model components, a number of significant performance enhancements as well as a prototype for the deep actor framework was developed.

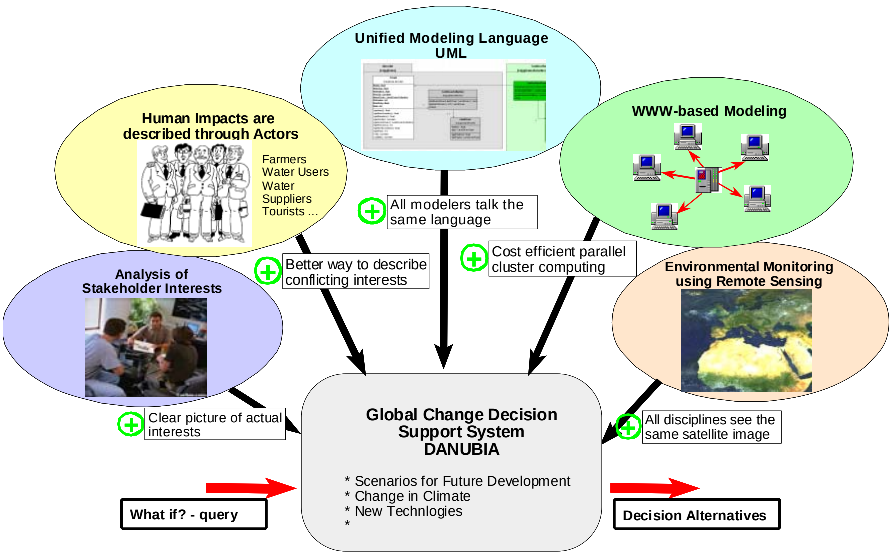

Fig. 1: Schematic sketch of DANUBIA and its integrative structure.

The coordination project profits from additional co-funding through the hosting university LMU and the Bavarian State Ministry of Sciences, Research and the Arts. These additional ressources, together with other resources from the coordinator, are being used for 3 purposes:

- To develop the Upper Danube Global Change Atlas as a communication tool with the stakeholders (see below)
- To develop an additional deep actors model, which models the decision making of ski tourists and the resulting traffic during winter weekends. It is intended to simulate future ski tourist traffic changes due to climate and demographic change. This module enables the coordination group to participate in the devlopment of deep actors models (see sectoral reports) and promotes the coherence between natural and social science projects within GLOWA-Danube (see below).
- Modelling wind induced snow transport in the Nationalpark Berchtesgaden. The cooperation with the meteorological groups has led to a test-area oriented project which will simulates lateral snow transport based on high resolution (200 m) MM5 wind-fields. This pro-

ject is conducted in close collaboration with the Berchtesgaden National Park Service (see below)

Ultimate goal of GLOWA-Danbue is to contribute to the development of a globally applicable instrument for the simulation and comparison of regional and sustainable strategy alternatives for a broad variety of environmental conditions.

2. Development and application of prototype Global Change scenarios

The first scientific validation runs using DANUBIA 1.0 were carried out for the 5-year period from 1995-1999. This allowed for a smooth spin-up especially of those models which show long time constants (e.g. groundwater). For the test run both meteorological drivers from German and Austrian station data as well as mesoscale simulations with MM5 were used. The results of these first validation runs were made public to the participating groups and were carefully analysed by all disciplines during a workshop. The analysis of the results showed that in principle all parameters were exchanged in a proper way. On the other hand the integrative analysis identified weaknesses in the simulations which were discussed intensively: most weaknesses are not due to wrong model approaches or implementation errors, but due to deficits in the knowledge of the processes involved and reflect state-of-art discussions in interdisciplinary research. Comparison with measured data revieled as main discussion points a strong over-estimation of snowfall in the Alpes through MM5 (which is due to scaling problems when coupling to complex terrain), a lack in transpiration (which is due to missing plant parameters for the model approach chosen) and very slow response of the groundwater model (which is also due to scaling problems in the interface between the surface model and the groundwater model). Generally the discussions clarified the specific needs for intensive research at the interface between atmosphere, land surface and groundwater on the chosen regional scale.

The actors models were confronted with the fact that changes (real and modelled) in the chosen 5-years period were generally marginal. Therefore it is hard to validate the reactivity of the actors models during such a short time period. On the other hand, it is difficult to establish reliable actors models for longer time spans for which changes could be observed or at least assumed.

Todays deficiencies in the capabilities to realistically model meteorological inputs to DANUBIA on the regional scale in complex mountainous terrain, as they showed up with MM5 and are also discussed in many other studies in the literature, are a serious stepping stone for a stakeholder dialogue and the future development of decision alternatives. These deficiencies currently prevent a credible simulation of future developments on the regional scale in the Upper Danube watershed, which has to go beyond climate change and include demograhic changes, land use change and new water supply technologies (only to mention a few). To initiate a discussion among the participating groups in GLOWA-Danube and with the stakeholders an alternative multi-stage technique was developed during a workshop to produce reliable future scenarios of meteorological inputs.

In a first step the complete DANUBIA is run for two 5-yeards periods which are taken from measured met-station data and are reshuffled from a wet and a dry year. Two scenarios are formulated (Strasser et al. 2005):

1. multiple, consecutive use of the year 2002 (after model spin-up). 2002 is an exceptionally wet and cool year.
2. multiple, consecutive use of the year 2003 (after model spin-up). 2003 has become famous as a very hot, dry year and is considered to be a candidate for an average year in 2100 if current climate trends continue.

This approach enables the investigation of the reactions of DANUBIA to two extreme weather series and at the same time uses measured met-data. In the center of interest is the reaction of the natural and socio-economical models to stresses which may build during these extreme weather series (water-stress, drought, floods etc.). The results of the scenario runs are being analysed by the project partners.

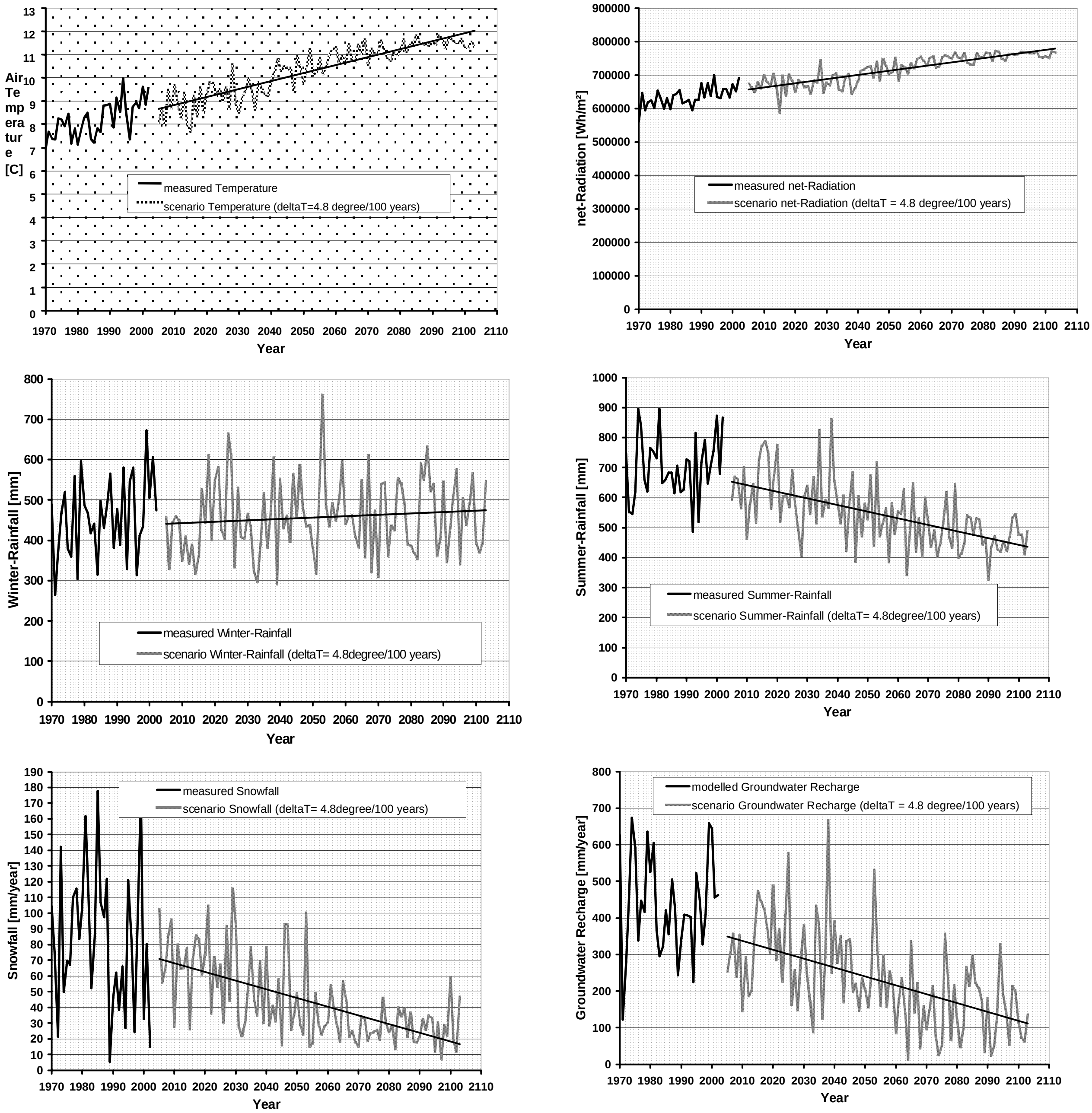

Fig.2: Results of secnario-run A2 (deltaT = 4.8 ^{o}C/100 years) for a conifer forest SE of Munich.

The second step is to simulate longterm climate change trends using the available measured time series of met data, which cover 270 stations during the period from 1970-2003. The complete data set is cut into monthly subsets. Based on a complex statistical analysis of the monthly values of temperature and rainfall in the measured met-data the monthly data sets are rearranged to create new time series of met-data. For this purpose a 2-dimensional random generator produces random monthly temperatures (which are supplied with a given temperature trend) and associated rainfalls. Given this, the most similar measured month is used for the rearranging process to create realistic meteorological time series, which show given temerature (and coupled rainfall) trends. As a basis for providing appropriate long-term meteorological input data sets for these first prototype scenarios, we used the IPCC temperature scenarios and generated time series of 100 years of future meteorological data from measurements. Besides the standard 0 °C scenario, which assumes that nothing is changing and that is run to show the long-term stability of DANUBIA, the IPCC scenarios A1, B1 and A2, which assume a global temperature increase for the next 100 years of 1.5, 2.8 or 4.0 °C were produced. Since IPCC for Central Europe assumes a temperature increase which is slightly above the global average we assume an increase of 1.6, 3.2 and 4.8 °C for our time series. The time series were input to DANUBIA (the scenario runs are actually computing at the time this report is written). Preliminary results for selected proxels were already analysed.

Fig. 2 shows the results of prototype scenario calculations for a conifer forest SE of Munich. The climate scenario is based on measured station data, the selected temperature trend is equivalent to IPCC-scenario A2 (deltaT = 4.8 ^{o}C/100 years). The annual values of the parameters air temperature, net radiation, winter rainfall, summer rainfall, snowfall and modelled groundwater recharge are shown. The groundwater recharge shows an impressive decrease which is due to a combination of increased radiation, decrease of summer rainfall and rainfall events in summer (which results in a decrease in interception and a resulting increase in transpiration) and a prolongued vegetation period due to temperature increase. Spatial calculations of the runoff generation in the Upper Danube for the 4 scenarios mentioned above are in progress. The results will be discussed at two stakeholder conferences with the agricultural and water resources stakeholders to be conducted in April and May 2005.

3. Analysis of water conflicts

The essential current and future conceivable conflicts and scenarios in the use of water in the Upper Danube catchment can be divided into internal and external, respectively. Internal conflict scenarios are expected for the fields of farming, drinking water supply, landscape protection, tourism and the concurring national and federal structures which are involved in the cultivation of water resources. Most interesting aspects in this respect are the content of nitrate in the groundwater, the decrease of the groundwater table, and the restructuration of the water supply. With the development of external conflict scenarios we start the investigation of the consequences of such water withdrawal in the catchment, and the ones of climate change for the water availability and its influence on a potential restructuration of industry (supply of services, chemical industry, semiconductor industry, aviation and astronautics).

4. Stakeholder dialogue

A stakeholder dialogue has been launched with the aim to define future scenarios, best guesses of risk as well as formulations of conflicts in an open, transparent process of using DANUBIA for finally illustrating the consequences of a variety of scenarios. The process by intention is not moderated by the GLOWA scientists. It is organized by a separate group at IFO-institute. Within the framework of stakholder conferences and discussion platforms, in which content sets are commonly formulated, different alternative scenarios will be discussed by analyzing the model results. The first two stakeholder conferences will be conducted until the status conference covering agriculture and water ressources. An easy to use, XML based visual interface is being developed for DANUBIA scenarios and results. It be based on the Upper Danube Global Change Atlas as a common visualization platform and will enable the stakeholders to participate in the development of new scenarios for future water use in the catchment of the Upper Danube.

5. Upper Danube Global Change atlas

To promote the visibility of our project, and to support the dialogue with the stakeholders we started to develop the concept for a Global Change atlas for the Upper Danube catchment, accessible to the public. This atlas is available in two versions: one as an online tool with a visual interface to select and display information as both maps of the catchment and time series for a predefined set of locations, the other as a representative collection of printed maps in an expandable volume (Fig. 3). Both versions of the atlas form a basis for the stakeholder dialogue and will be continuously updated together with the stakeholders during the second project phase. The content of the atlas includes maps of the DANUBIA database (e.g., relief, river network, landuse, meteorological stations), sectoral project data (specific model parameters, e.g. hydraulic conductivity), and, more important, the scenario results. It is planned to discuss the scenario results with the stakeholders on the basis of the content of the atlas. Conflicts among the stakeholders and between the stakeholders and science should be solved by aiming at common decisions of what to include into the atlas. The atlas will therefore serve as an open discussion platform. On the other hand, the development of the online version of the atlas represents a first step towards an automtic scenario result processor, i.e. a procedure to read, analyze and visualize the results from DANUBIA scenario runs.

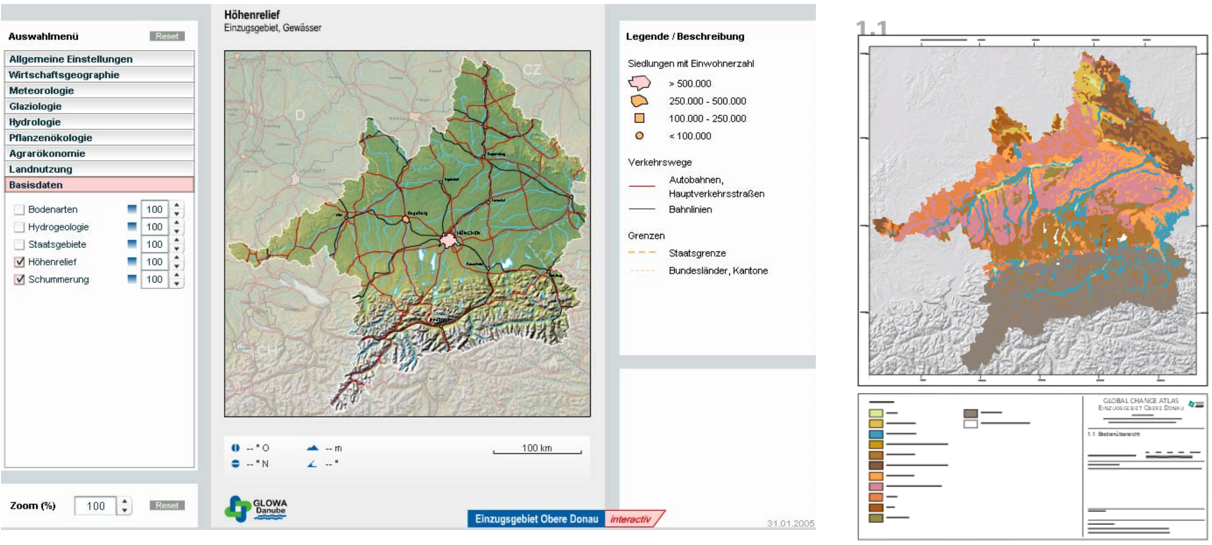

Fig. 3: Upper Danube Global Change Atlas: online (left) and printed (right) version.

6. Modelling vehicular traffic flow

The activity to develop a model to simulate vehicular traffic flow was initialized for the 2nd project phase in addition to the GLOWA-Danube project proposal. It aims at delivering an example for modelling decision making within the deep-actors-framework. Moreover, it supports the results of the project group “tourism” by supplementing simulations of touristic demand concerning issues in local recreation and modelling the induced traffic flow. As a first prototype, we have developed the macroscopic traffic flow model DaTraM (Danubia Traffic Mode, Siebel & Mauser 2005), which simulates traffic flow in a general road network. DaTraM is based on vectorial street data for the Upper Danube catchment. Prescribing the relevant origin-destination-flows the model ensures that cars reach their destination within the shortest travel time. Internally, DaTraM describes traffic flow using methods from fluid dynamics (similar to the Phillip equation). The model is completely implemented in JAVA. For a realistic description of vehicular traffic it was necessary to calibrate the parameters of the underlying 12 road types. At the same time we worked on the visualization of DaTraM, which is essential for the understanding of traffic dynamics. For the special case of ski tourism we developed an algorithm describing the decision process for daily trips from the forelands into the mountains (Fig. 4). This algorithm is based on the “deep-actors-framework” and yields the relevant origin-destination flows for DaTraM.

The model development and calibration of DaTraM is now completed and allows the simulation of first traffic scenarios. The decision algorithm, which is based on spatially distributed socio-economic datasets, which were acquired from microm GmbH, will be implemented in close collaboration with the DANUBIA actors within the course of 2005.

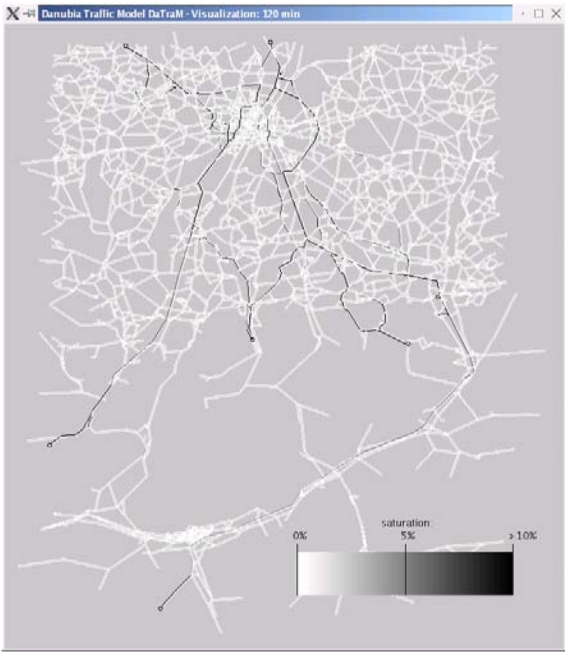

Fig. 4: Traffic network covering parts of southern Bavaria and Austria after one hour real time. The dense agglomeration of roads at the top represents Munich, the agglomeration of roads at the bottom (towards the left) represents Innsbruck. The source nodes at the top are the highways A8 and A9, and the destination nodes distributed over the network are Garmisch-Partenkirchen, Lenggries, Bayrischzell, Brannenburg, and Stubai, respectively.

7. Modelling wind induced snow transport

A further activity of our project group is the development of an algorithm for lateral flow at the subproxel scale in our test site Berchtesgaden National Park. The processes we chose as examples for lateral flows are the wind-induced snow transport processes saltation and suspension: they lead to a significant variability of the snow cover in space and time due to erosion and deposition. Knowledge about this variability is important for determining the temporal course of the snowmelt runoff. Our first DANUBIA results have shown that in the mountainous region of the catchment there ist still room for improvement of the spring snowmelt dynamics. Furthermore, in rugged terrain pronounced interception losses of snow through transport or snow on canopy stands can have important effects on the water balance, too. The concept of our lateral flow algorithm can later be adopted for modelling of the snow cover at the subproxel scale by implementation of the geocomplexes which have been investigated during the first project phase (see sectoral report from "Hydrology/Remote Sensing); with our results in the test site, we can provide a data base for the Danube project group SNOW to derive a topography dependent parameterisation for wind induced snow redistribution at the DANUBIA catchment scale.

Since interpolation of wind speeds and directions of station data cannot deliver adequately precise spatially distributed wind fields, we use MM5 generated and downscaled local wind fields for the Berchtesgaden test site at a resolution of 200 m as the driving force for the snow transport processes (Fig. 5). The most typical atmospherical situations were chosen, the wind fields calculated with MM5 and the results packed into a library file. From this library file appropriate wind fields can be selected by using 700 hPa wind speeds and directions from the DWD Lokalmodell for the test site region as a key for looking up the respective MM5 situation from the library at each model time step. For now, the wind field library has been built up (Bernhardt et al. 2005) and the snow transport model development has begun. In 2005, first results of the redistribution of snow induced by wind szhould be available.

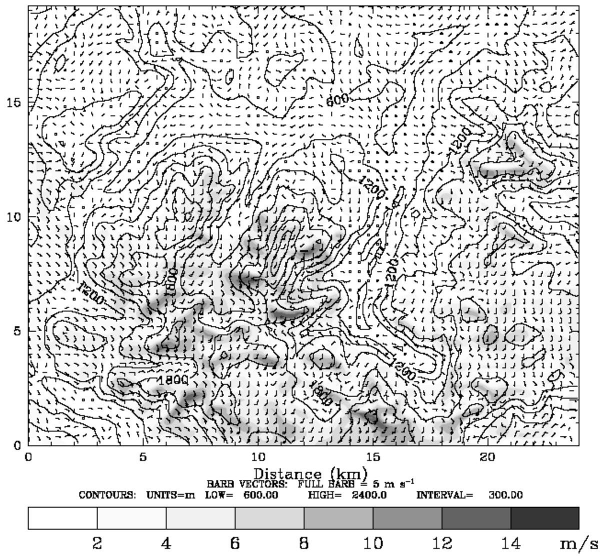

Fig. 5: MM5 derived wind fields for our test site in the Berchtesgaden Nationalpark. The vectors represent wind speed and direction for an atmospheric flow of 315° and 25 m/s in the 700 hPa niveau.

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GLOWA-Danube

CONSEPTUALISATION, REALISATION AND EVALUATION OF THE PROBLEM-ORIENTED AND COMPUTER-BASED PARTICIPATORY APPROACHES FOR USE OF THROUGH GLOWA-DANUBE INTERESTED STAKEHOLDERS ("STAKEHOLDER PARTICIPATION")

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Key words: Participatory Approaches; Integrated Environmental Assessment; Danube River Basement Modelling.

Abstract
In the GLOWA-Danube project, a simulation based instrument has been develop with the assistance of the decisions-support system DANUBIA that gives the user the ability to examine scenarios for changes in water balance as well as support in the selection of courses of action with regard to sustainable water management. The project faces the task of designing the development and use of DANUBIA in dialogue with the social stakeholders that are still to be identified. To give a methodological consistency to this dialogue, an informal procedure for the participation of stakeholders will be systematically developed that addresses the problems, and that is operationally planned and experimentally proven. In addition, the quality of the results will be improved by an on-going evaluation and the results and experiences will be presented to the public in a suitable form.

With the thorough integration of stakeholders, a decisive contribution can be expected both for the validation of the system with respect to its practicability as well as its concrete usefulness. In order to support the usability of DANUBIA by non-experts, an adaptive user interface will be created that can be interactively adapted to a user profile, thus permitting an individual use of DANUBIA and a transparent presentation of results.

The task of the stakeholder participation is also of central importance for the model-supported management of river catchment areas. On the one hand, the question arises for decision-supporting models as to the concrete application, societal relevance and practicality aptitude and consequently the overcoming of the oft occurring "paradigm lock" between science and its respective environment.

Decision supporting models serve the purpose of making knowledge more manageable for stakeholders. In this respect, stakeholder participation serves the examination of practicality and user convenience of such models and consequently the new paradigm of participatory, interactive processes.

On the other hand, stakeholder participation is an integral component within the framework of the management of river catchment areas. the new EU water directives require that public participation must be involved in the preparation of control plans.

In order to do justice to the objectively and politically necessary task of the enabling and use of participatory processes vie the application of decisions-supporting models, the participation of the relevant interest groups that is suited to the problem and those affected is required in the context of GLOWA Danube.

The planned communication between model developers and interested parties or interest groups in the form of stakeholder participation has proved to be largely new territory in this case. To be sure, as mentioned above, there are examples of a dialogue between science and different interest groups in the meantime. Nevertheless, the mere fact that with these instances of dialogue, scientists and (non-scientific) interests groups come together fur a round-table discussion, for example, does not in itself elevate these activities to stakeholder participation. As interesting as discourse procedures that enhance communication may be, there is frequently the danger that they remain arbitrary in terms of method. Also within the framework of the GLOWA projects, there is the danger of an arbitrary interpretation and organisation of stakeholder participation due to lacking relevant models and experience with respect to stakeholder participation.

To avoid this, a structuring and developing of the participatory procedure that is adequate to both the problem and the people involved is necessary. This procedure must include, on the one hand, the necessary objective knowledge on the capability, the possible applications, the range and quality of the expected results and, on the other hand, must safeguard professionalism in implementation as well as efficiency and the quality as results by means of on-going assessments. Against this background, this subproject has three basic objectives:

Objective 1: Conception of an informal participatory process that is adequate for the problem and the people involved

The objective is the selection and general conception of a participatory procedure that is adequate for the problem and the people involved, where possible through the use, combination and adaptation of several procedures.

Objective 2: Planning and realisation of the developed participatory procedure

On the basis of the general concept for the planned stakeholder participation, it is important to plan in detail and implement the selected participatory procedure. In this way the chances for stakeholder participation will be used for concrete work in and with DANUBIA and an effective and efficient exchange be between model developers and stakeholders can be achieved.

Objective 3: Evaluation of the experiment

The successful testing of informal participatory procedures in the development and use of a decision-support system is in itself an important but not yet sufficient result. In the light of increasing importance of the dialogue between the science and the public, a know-how transfer from the subprojects is a central concern, in order to avoid extensive development efforts and operational mistakes in the organisation and realisation of stakeholder participation processes in similar projects.

In this respect the important task is to accompany the participatory process, to safeguard and systematically evaluate the results and to organise an evaluation of the process. In addition the experience from the participatory procedures should be present to the public and other institutions in the form of guidelines.

Results

Compared to the other Glowa-Danube subprojects the Stakeholder participation project has only started in April 2004. So far, the review on existing literature has been completed (Sprenger/Wieland 2004).

As a result of this literature review and subsequent discussions with the other researchers the participatory approach will occur in three operational steps.

The first cycle of activity will focus on:

- Improving stakeholders understanding of DANUBIA;
- The Nature, appropriateness and adequacy of the DANUBIA model;
- The quality of the data sets used to populate the model;
- Ways to fill data black holes.

The second cycle of activity aims at serving the purpose of developing a baseline scenario for the period from 2003 to 2010.

The third cycle of activity then will focus on:

- Changes in the key assumptions in the baseline scenario as well as in the application and effects of other policies and measures (Sensitivity of the projections to alternative assumptions).

The participatory approach will use the forms of focus groups and in-depth groups (De Marchi et al. 1998).

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DANUBIA: A WEB-BASED MODELING AND DECISION SUPPORT SYSTEM FOR INTEGRATIVE GLOBAL CHANGE RESEARCH IN THE UPPER DANUBE BASIN

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Keywords: integrative simulation, distributed system, object-oriented framework, multi-actor approach

Abstract:
The central task of the computer science group is the development of the integrated simulation and decision support system DANUBIA as a tool to study water-related scenarios and to support a sustainable water resource management. After the first phase of the project the DANUBIA system is able to perform distributed, coupled simulations where the single simulation models of all participating disciplines run concurrently and exchange (through their interfaces) dynamically information over the network; cf. [1]. For the realization of DANUBIA an object-oriented framework has been developed which comprises management components and facilities to plug in the simulation models of the various research groups.
During the first year of the second project phase the DANUBIA framework has been extended in three directions. First, the usability and flexibility of the system has been improved by enhanced controlling and monitoring mechanisms and by supporting flexible, individual configurations of integrative simulations. Secondly, in order to be able to perform long-term simulations within a reasonable amount of time, the performance of DANUBIA has been thoroughly analysed which led to efficient implementation strategies that have increased the performance of DANUBIA by the factor 6.4. Finally, the computer science group has investigated a general multi-actor concept which is already partially implemented in the extended DANUBIA framework and can be used by all actor groups within GLOWA-Danube to design and implement their deep actor models. For all tasks object-oriented software engineering methods have been applied on the basis of the Unified Modeling Language UML [2] which is still successfully used by all partners as a common graphical notation for modeling the integrative aspects of the system. In the following we briefly summarize the outcomes of the above mentioned research activities.

Results:

1. DANUBIA Core System – Refactoring and Enhancement

To improve the usability and flexibility of DANUBIA the system had to undergo a revision process for which refactoring techniques proposed in [4] have been applied. The first goal was to make the simulation system more flexible in the sense that an arbitrary subset of the existing simulation models can be coupled within an integrative simulation. For this purpose the network communication between simulation models has been refactored such that the many individual static proxy classes (that have been used for each model to hide network issues from the model developer) are replaced by a single dynamic proxy class that supports the dynamic generation of arbitrarily many model interfaces at runtime. Thus flexible configurations of simulation models for integrative simulations can be constructed. This has the particular advantage that the distributed simulation system can now be used by the model

developers as an enhanced test environment running on a single computer or on a small local area network. Hence we have achieved a unification of the former distributed runtime environment and the former local test environment to the so-called core system of DANUBIA.
To improve the usability of the system the number of system processes an administrator has to handle when starting a distributed simulation has been reduced. For this purpose a new managing component is provided that combines functionalities that were formerly performed by several different system processes. Additionally the component checks whether a simulation configuration is valid, i.e. whether all import interfaces of the single simulation models are resolved by corresponding export interfaces of their partner models. In order to control a simulation run a graphical user interface, the DANUBIA monitor, has been developed which displays the current system state. For instance, **Fig. 1** shows a screen shot of the DANUBIA monitor which displays the list of registered components participating in the current simulation and the status of the timecontroller which coordinates the single simulation models to work properly together during the simulation period.

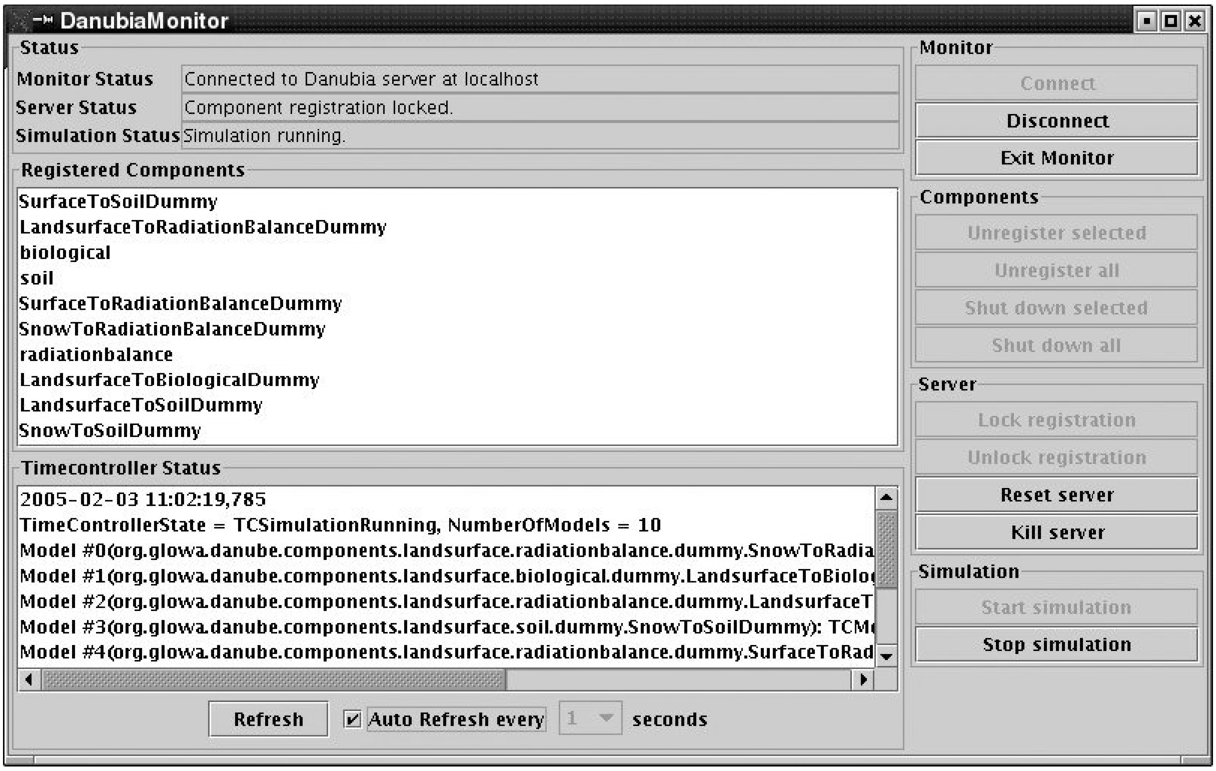

Fig. 1. The DANUBIA monitor

2. Performance Enhancements

A reasonable computational performance of DANUBIA is a crucial factor for performing long-term simulations in an acceptable time and for reducing the susceptibility to technical errors like network or hardware failures during a simulation run. The first reference runs with the DANUBIA system in early 2004 took about a month for a five years simulation period (or 56 seconds for one hour simulation time). This would scale up to half a year of computation time for a 30 years simulation. Therefore much effort was put into enhancing the performance of the DANUBIA system.
First, the performance impacts of the proxel-based computation approach and the use of Java

have been analysed. For this purpose quantitative runtime measurements were carried out showing that the biggest influence on performance is due to

- data types and data transfer,
- logging, i.e. producing auxiliary textual output to trace a component's execution and
- checking of import and export data during model communication.

In order to address these aspects the following main actions were taken: optimization of the data type design and implementation, extension of the DANUBIA framework to support faster logging and data checking methods and to support further parallelization of computation phases within a single simulation model. A quantitative analysis has shown that the optimized Java implementation is only 20 percent slower than an equivalent implementation in C. The total result of all efforts put into the performance enhancement of DANUBIA was a strong performance increase by the factor 6.4 which means that a five years simulation period from the first reference run can now be performed within four days (more precisely, one hour simulation time takes 8.7 seconds) and a 30 years simulation run could be carried out in less than a month computation time. Hence, the basis for performing long-term simulation runs and for studying long-term scenarios is provided with the new version of DANUBIA. **Fig. 2** shows the factor of the performance increase for every model of the landsurface (whereby not only the total performance increase is depicted but also the performance increase of each of the computation phases “getdata”, “compute” and “commit” occurring periodically in each computation cycle; see [1]) .

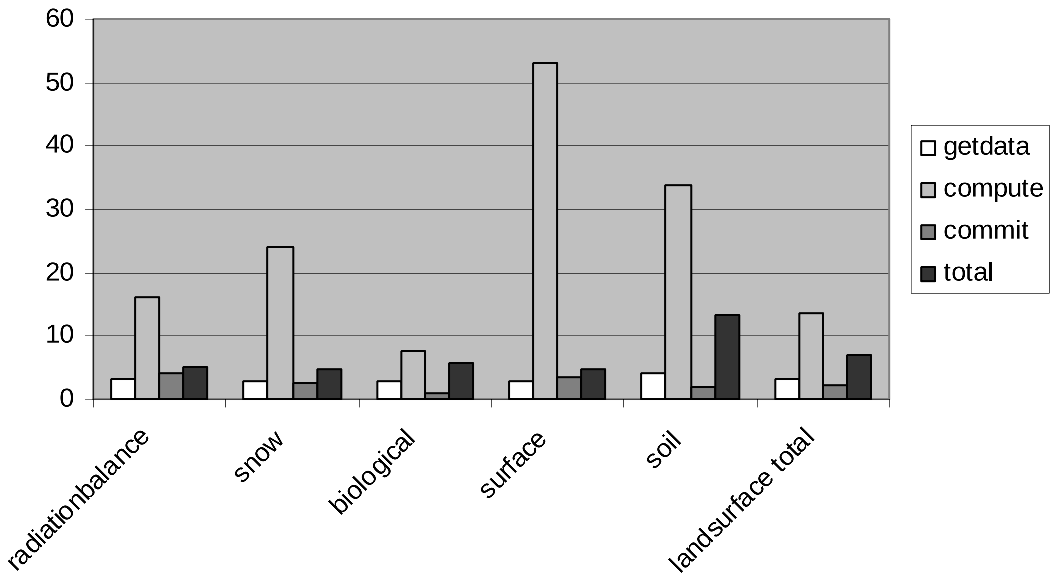

Fig. 2. Performance enhancement of the landsurface models

3. Multi-Actor Approach

The actor groups in GLOWA-Danube map acting entities (actors) of the real world, such as farmers, water suppliers, households [3] etc., to objects which simulate their (water-relevant) behaviour. An actor model administrates and runs a set of actors during a simulation period. In contrast to the “flat” actor models developed during the first phase of GLOWA-Danube the “deep” actor models take into account decision making processes of their actors. In order to move from flat representations of acting entities to deep models of their behaviour, a multi-actor approach has been investigated that unifies the general concepts behind all decision making processes considered in the socio-economic research groups. The multi-actor approach has been implemented in the object-oriented deep actor framework which extends the DANUBIA framework by interfaces and abstract base classes to be used by all actor groups to model and implement their specific actors and decision making processes.

As shown in Fig. 3 the deep actor framework comprises (among other things) a base class AbstractActorModel which is extended by particular deep actor models like, e.g. DeepHouseholdModel. The class AbstractActor serves as the base class for implementing the behaviour of particular actors, like e.g. DeepHouseholdActor, which are administrated by their corresponding deep actor models. Decision making of an actor is realized within a computation cycle whose general pattern uses methods provided by the interface ActorComputation. The computation cycle essentially consists of an observation of the environment via sensors (interface SensorQueries) and a selection, based on these observations, of a subset of initial plans that are available through the interface CoreActorProperties. The selected plans then become active and can be accessed for further filtering steps via the interface PlanMapSelection. The execution of the remaining set of active plans follows a general template that is implemented in the class AbstractActor. During their execution of course the values of corresponding proxels within the simulation area can be affected. After the execution of plans an actor may export data to other actors and, if necessary, create a history entry (which may be used in the next simulation steps).

The actual implementation of the deep actor framework provides a prototype which will be further elaborated by taking into account the experiences of the ongoing implementations of concrete deep actor models and their integrative simulation runs.

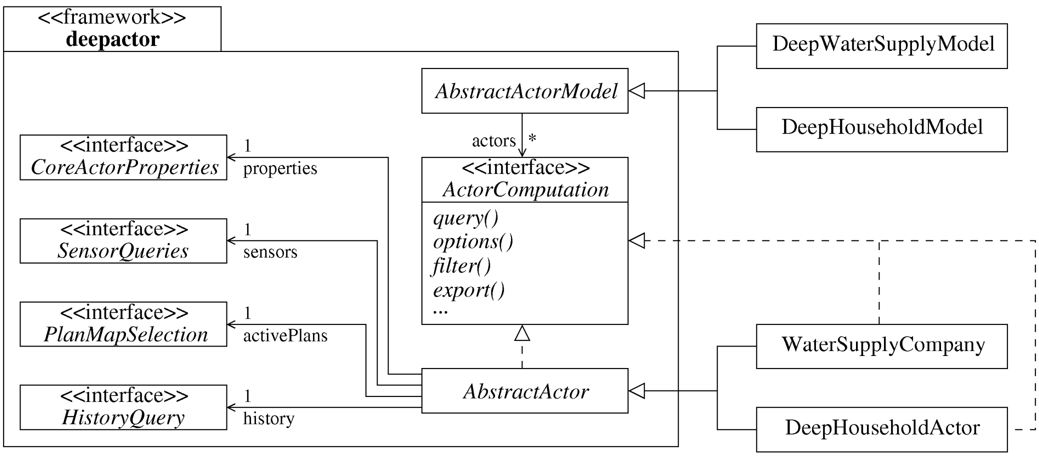

Fig. 3. Deep Actor Framework

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MODELLING FLUXES OF WATER, ENERGY AND MATTER AT THE LAND SURFACE USING REMOTE SENSING

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Abstract
Hydrologic investigations in the reporting period focus on the improvement of soil parameterization, the development of a phyically-based soil heat transfer model, the completion of the scaling algorithm 'Geocomplexes' and the continual scientific and technical improvement of the DANUBIA sub-components Surface, RadiationBalance, Soil and Atmostations by means of sensitivity analysis and validation. Remote Sensing issues concentrate on the development of scale-independent procedures to provide reliable input- and validation data for DANUBIA. MODIS and ENVISAT-ASAR imagery is used to retrieve spatial information on leaf area index and near surface soil moisture. Integrative development includes a regionalization and validation concept for hydrologic fluxes between the model components Landsurface, Groundwater and RiverNetwork, an interface to the Actors component, a nitrogen transformation and transport scheme in collaboration with the Biological component, and a scenario engine for climate change based on measured data.

Results - Hydrology
- A physically based soil heat transfer module has been developed, tested and implemented in the DANUBIA model component "Soil" (replacing an earlier conceptual version). It is driven by the ground heat flux provided by the component *RadiationBalance*. An analytical approach provides the temperature below the soil compartments as the lower boundary condition for the heat transfer equation. Field measurements have been used for validation.
- The GIS-based fuzzy logic procedure SoLIM (*Soil Land Inference Model*) for the improved spatial parameterisation of the soil model has been incorporated and is currently being adapted to the requirements of the DANUBIA system. A knowledge data base, comprised of multi-scale information (e.g. high resolution soil maps, DEM and land use), is used to generate better resolved spatial distributions of soil hydraulic parameters.
- The scaling procedure "Geocomplexes" has been completed (Reichert et al. 2004), which describes each proxel as a composition of diverse homogeneous units of vegetation, soil and topography, for which all fluxes can be indidvidually determined and aggregated for export as single values to the adjacent model objects. Its objective (providing equivalent process descriptions across scales) has been successfully evaluated in DANUBIA's test-environment. Sensitivity analyses has been performed for event-based and continuous simulations, indicating that the procedure fully preserves the relevant hydrologic information while substantially reducing spatial heterogeneity and computational effort.
- The DANUBIA subcomponents *RadiationBalance*, *Surface*, *Soil* and *Atmostations* have adapted all necessary technical developments. The stage of model implementation in the framework of DANUBIA is functionally and technically completed. Continual improvement of process decription is achieved through algorithmic analyses and validation measurements.

Results - Remote Sensing
- A software was developed and implemented to perform a scale independent segmentation of coarse scale surface reflectances based on high resolution land cover information and a fuzzy description of reflectance characteristics. The software models land cover-dependent reflec-

tances from parallel aggregated Landsat TM data and MODIS data for evaluation of the procedure. The data enhancement showed good results in introducing a higher spatial precision for the derivation of LAI from a set of 19 MODIS scenes of 2003. A database of fuzzy descriptions of time coupled reflectances was generated based on field measurements and the application of coupled biological and atmospheric radiative transfer modelling.

- A semi-empirical model for the retrieval of near-surface soil moisture has been adapted to Envisat's ASAR-WSM microwave imagery. A scaling procedure was developed taking into account subscale land cover datasets derived from AVHRR imagery. Quantitative comparisons of derived near-surface soil moisture products to field measurements and mesoscale hydrologic model results show good agreement. The validated soil moisture data derived from ASAR is aggregated to create virtual footprints of future ESA's SMOS soil moisture sensor. The variability of soil moisture patterns monitored from upscaled multitemporal ASAR imagery compares well to the dynamics of soil moisture simulated with DANUBIA (Mauser et al. 2004). This scheme provides a new, independent and spatially transferable method of validation for the simulation of soil water fluxes in hydrologic modelling.

Results - Integrative Activities

- In collaboration with the component *Biological*, a model for the simulation of nitrogen transformation processes has been incorporated in the component *Soil*.
- A regionalization scheme for the integration of hydrological, hydrogeological and hydraulic process models (*Landsurface*, *Groundwater* and *RiverNetwork*) has been conceptionalized and implemented. The heterogeneity of the physical environment in the Upper Danube is accounted for by means of hydrographic segmentation, providing specific coupling solutions for the alpine and cristalline parts of the watershed. The qualitative and quantitative performance of the model system has been tested and validated over several heterogeneous 5-year model time frames using a multi-response validation strategy (e.g. soil moisture, groundwater levels, gauged runoff, water balance on sub-catchment level).
- A climate change 'scenario engine' has been developed, which allows for an automatic or interactive re-arrangement of climate data based on the statistical analysis of a 34-year period of approx. 270 meteorological station recordings
- The research group has participated in the conception, generation and validation of the new 'upscaledLanduse' distribution for the Upper Danube watershed, based on remote sensing data, GIS operations and statistical data, to represent all occuring (sub-scale) land cover types
- Scenario runs of DANUBIA (assuming either exceptionally dry or wet conditions) have conjointly been analysed for impact on the hydrologic cycle and water availability
- An interface to the *Farming* component has been established and is put into practice, exchanging information on the actual soil conditions for agricultural treatment and the application of mineral and organic N and P fertilizers.

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GROUNDWATER MANAGEMENT AND WATER SUPPLY

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Keywords: Groundwater, Three Dimensional Flow Model, Water Supply, Actors Model

Abstract

Within GLOWA-Danube, the research group 'Groundwater' develops a model for the three-dimensional groundwater flow and a model to simulate the water supply system in the Upper Danube Basin. Both models were integrated in the DANUBIA modelling framework using the conceptual UML modelling approach and have been validated and subsequently used to simulate scenarios. The DANUBIA object **GroundwaterFlow** *was implemented in JAVA and wrapped around the original MODFLOW Fortran code. Interfaces exist mainly to the* Actors *component (withdrawal, quality), the* RiverNetwork *component (exchange with surface water bodies, river stages) and the* Soil *object (groundwater recharge, groundwater level). The numerical groundwater flow model was developed mainly in the first phase of GLOWA-Danube using MODFLOW (McDonald & Harbaugh, 1988) based on a conceptual hydrogeological model of four layers. The object-oriented DANUBIA object* **WaterSupply**, *a member of the Actor package, is a proprietary development and was implemented entirely in JAVA.* WaterSupply *is in essence an interface and interpreter between the natural science models determining water supply on the one side and the socioeconomic, behaviour-driven* Actors *models governing demand on the other. Main interfaces in DANUBIA exist to* GroundwaterFlow, RiverNetwork *and the* Actors *objects* Household, Economy, Farming *and* Tourism. *Through a comparison of supply and demand based upon the actual organization of water extraction and distribution within the upper Danube catchment,* WaterSupply *aims to identify areas which may suffer water stress (Barthel et al., 2005).*

Results

During the reporting period (~2004) the object ***GroundwaterFlow*** was consistently and permanently improved based on local model runs and the evaluation of coupled DANUBIA simulations. The main enhancements during 2004 were the full integration of the alpine and the crystalline regions of the catchment into the flow model, the switch to the MODFLOW 2000 code as well as major improvements of the interfaces to the *RiverNetwork* and *Landsurface* (object *Soil*) components. Along with the conversion to the new MODFLOW 2000 code, the parameterization of the model was partially extended by making use of automatic calibration. In addition the model geometry was improved using an automatic algorithm (Wolf et al., 2004) which also includes a first basic approach to up-scaling of hydraulic parameters. Regarding the interface to *Soil*, major progress was achieved by applying a spatially differentiated treatment of the exchange parameter *GroundwaterRecharge*. The interface to *RiverNetwork* was improved by a more realistic parameterization of the infiltration algorithm, based on river morphology (width, discharge, depth and elevation). In order to carry out a full joint calibration of the objects *RiverNetwork*, *Soil* and *Groundwater*, first conceptual steps were agreed upon and implemented. The major progress, however, was made through the new concept of including the alpine sections of the basin in the flow model. The alpine (mostly Austrian) areas form more than 30% of the area and receive 50% of the precipitation. The coupling of the resulting groundwater recharge to the aquifers of the valleys and lowlands was achieved by linking all the alpine *Proxels* to a specific quaternary aquifer cell (linkage based on the DEM flow direction set), thereby routing the fast flow components in a realistic way to the groundwater system. Approaches to solve the problems of incorporating the alpine and the deep saturated zone are described in Rojanschi et al. (2004). The integrated modelling of Nitrate transport has been postponed in an agreement between the relevant groups and the project coordinator. However, three master's theses related to the topic were already submitted (see e.g. Vasin & Barthel, 2005).

The results of ***GroundwaterFlow***, which originate from a coupled simulation carried out in January 2005 for the years 1995 to 1999, can be characterized as follows: The overall behaviour of the model is now very good. Previous problems such as flooding and drying out of cells as well as numerical instabilities of all sorts have now apparently been solved. This can be contributed mainly to the adjustment of the model geometry and the enhanced parameterization. An internal evaluation of the MODFLOW results shows that the balance error (inflow - outflow) is less than 1%, which can be considered to be quite good. The calculated piezometric heads and water levels are generally acceptable when compared to measured mean values (overall $R^2 = 0.95$ for steady state results) and time series. However, big differences exist in various parts of the basin as well as for various aquifer sections. Generally, the deviations from the natural situation are small for the unconsolidated, quaternary aquifers that fill river valleys and gravel plains (layer 1) but large for the jurassic Karst, the Alps, the crystalline regions and parts of the Tertiary. Since the Quaternary Aquifer is the most important for the short to medium term (days to several years) exchange of the groundwater with surface water bodies and the atmosphere, this is in many cases acceptable. In some cases deviations occur as a result of complex hydrogeological conditions which cannot be accounted for at the scale chosen in DANUBIA. In some cases the errors are clearly invoked by wrong parameters that will be adjusted as far as possible in the future. Looking at the model results from the outside, i.e. at the data exported to the other models, the results of the 1995-1999 run are less convincing. Namely, the amount of groundwater infiltrating into the rivers (*InExfiltration* to *RiverNetwork* component) is far too high, resulting in a unrealistically high river discharge, especially in 1995 and 1996. In addition, the infiltration is too high in the Alps and, respectively, too low in the lowland parts. The cause of this error lies in the starting heads used in the transient simulations which were considerably too high, in the Alps (0.5 to 2.5 m). This way, the model looses unrealistically high amounts of water in the beginning of the simulation from the groundwater storage. The starting heads were previously calculated using a steady state simulation, where they proved to be acceptable. In the meantime the initial values have been corrected. The problem shows, however, the relatively slow reaction time of the groundwater flow model and its long-term 'memory'. A related problem manifests itself in the dynamics of the flow model, which are significantly slower than the dynamics observed in nature. It remains unclear whether this is a result of the scale and the numerical schemes applied or if this can be enhanced using a better or different parameterisation.

Major improvements of the object ***WaterSupply*** during the reporting period were the completion of the water supply database, the implementation of the fully object-oriented model concept, the development of an approach for calculating the water price and the conceptualization of a prototype '*deepActor*' with decision-making capabilities. The completed water supply database encompasses the public drinking water supply of the German, Austrian and Swiss sections of the catchment with over 2400 community, group and long-distance suppliers. It represents the only comprehensive and consistent collection of water supply data for the upper Danube basin. The object-oriented *WaterSupply* model concept was successfully implemented for the entire model area. At the centre of this concept stand the two classes 'water supply companies' (WSC) and 'communities', the latter representing the water users modelled by *Household*, *Tourism*, *Farming* and *Economy*. At run-time, 'instances' of the WSC class, drawing upon information from the WSC database, *Groundwater* and *Rivernetwork*, fulfil the community water demands to the degree physically or legally possible. The object-oriented *WaterSupply* model was included in the DANUBIA scenario runs at the end of 2004. An approach for calculating the water price based upon statistical data has been developed in a joint effort with *Economy*. Here, the influence of a number of company-specific and region-specific, partially time-dependent variables upon the water price was determined by means of regression analyses (see report of *Economy*). In the latter half of 2004, the focus shifted towards the conceptualization of a general '*deep Actor*' concept and model framework together with the Computer Science group and the Actors groups. Parallel to this, the specific details (i.e. decision-making rules) for a *deepWaterSupply* model have been elaborated in view of the current joint implementation of a prototype *deep Actor* together with the Computer Sciences group and *Household* (see reports of the *Household* and the Computer Sciences group). As opposed to the 'flat' actor models, which represent the actual situation, the '*deep*' models will contain decision-making capabilities to allow the actor to respond to a changing environment (e.g. climate, water availability, etc.). In the case of *deepWaterSupply*, the individual water supply companies will be able to decide upon a strategy for ensuring water supply within limited boundaries.

The ***WaterSupply*** model has been validated within the integrated system for the reference period 1995-1999. Within this period, exceptional results were neither expected nor calculated. Being a linking part in an integrated system, the 'results' are highly dependent on the results of the connected models. A 'good result' of *WaterSupply* is achieved if all the demands can be satisfied following the predetermined patterns of water distribution in the real world. In other words, as long as the model represents the current real world situation correctly, the results remain undramatic. From the decision makers point of view, interesting results are only to be expected in cases where the present day situation, which is characterized by an almost 100% satisfaction of demands, is disturbed, e.g. by extreme climatic conditions. The model runs for the reference period showed an under-supply for a small number of communities (~1% during winter, 2% in the summer) in the year 1999. Since no water scarcity is known for 1999, a water deficit has to be considered an error. At present it remains unclear if the error lies in the object *WaterSupply* itself or somewhere else in the integrated system. Possible sources of error might be found either in the *WaterSupply* data base but might also originate from the export values of the partner models or their import values respectively. Finally, it has been found that the statistics are not consistently reliable.

Currently, great efforts are being made to further merge the ***GroundwaterFlow*** and the ***WaterSupply*** objects in order to fulfil the task of creating an integrated tool for Groundwater Resources and Supply Management. This is especially important for the development of *deepWaterSupply,* which will be designed to decide on specific plans and actions based on analyses of parameters calculated by the *GroundwaterFlow* object. The task of the latter is here to calculate resource availability using key parameters that describe the state and trends of groundwater resources. An integrated spatial and temporal evaluation of several export parameters form the basis of an approach which is currently being developed.

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GLOWA-Danube

STREAMFLOW AND WATER QUALITY MODELLING IN THE UPPER DANUBE CATCHMENT: INTEGRATION OF TECHNICAL STRUCTURES AND DETECTION OF CAPACITY STRAIN

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Key words: nitrate-transport-model, water-temperature, level-pool-algorithm, sewerage systems

Abstract

During the report period the main work of the surface water research group consisted of a comprehensive enhancement of the rivernetwork-component structure, the improvement of existing modules concerning nitrate transport and water temperature, the integration of a new algorithm accounting for flood attenuation caused by reservoirs and lakes, and literature work in the context of the intended synthetic generation of sewerage systems. Integrative work has been done primarily concerning the interfaces to the components landsurface and groundwater, further on also concerning the components tourism, economy and household.

Results

The GLOWA-Danube - subproject "surface water" models the streamflow and the fate of water-quality constituents in networks of open channels in the Upper Danube catchment. The former *rivernetwork*-component, developed in the first GLOWA-Phase, could only handle a river network with a defined structure: smaller creeks in the upper part of the catchment, modelled by muskingum, and exactly one connected system of main rivers and streams in the lower part of the catchment, modelled by the more complex DAFLOW-approach. In order to incorporate technical structures like reservoirs or sewage networks at any point, this simple structure had to be dissolved in favour of a more general one. Therefore, an object-oriented approach was implemented, where any part of the river network (proxels or a group of proxels) may be modelled with any modelling approach implemented. In this way it is possible to place new structures like natural lakes, artificial reservoirs or urban sewerage systems wherever needed. The only presumption is that each proxel may only belong to one single object. Objects are allocated within the pre-processing phase. All existing interfaces to other DANUBIA-components work as before.

The water quality model BLTM with its full consideration of advection, dispersion and reaction kinetics can only be applied to medium and large flowing waters, where DAFLOW delivers the essential hydraulic parameters. Therefore the problem arises of how to model the transport of constituents (mainly nitrate) accruing in the upper catchment to the DAFLOW-network. We solved this problem by implementing a simplified transport model for constituent loads, not taking into account any chemical or biochemical reactions. The process of load transport is modelled by a specially adopted muskingum approach. This assumes that the process of load advection and dispersion is equivalent to the process of translation and diffusion, modelled by muskingum. Applying the simplified method we achieved Nash-Sutcliff-efficiencies between 0,11 and 0,91 with a mean of 0,532 calculated at 15 Bavarian water quality gauges (after mass-correction eliminating the effect of nitrate-influx along the reaches).

BLTM in its original form cannot deal with water temperatures near zero degrees in a meaningful manner (Jobson / Schoellhammer 1987). Since air temperatures below zero degrees are quite normal in winter months in the Danube-catchment, a conceptual correction of the water equilibrium temperature calculation was introduced for cases when air equilibrium temperature falls below 4°C. We are in contact with the model developer in order to discuss the problem more extensively. By applying the correction, Nash-Sutcliff-efficiencies could be increased from 0.558 to 0.896 (calculated at Fischenpegel / Ammer).

The former rivernetwork-component was not able to consider storage-processes in natural lakes and artificial reservoirs, which are mainly determined by the volume of the water body and geomorphologic and hydraulic properties of the outlet. Concerning some Bavarian lakes, these aspects were analysed in detail by Henselmann (1970). In order to calculate the effect in a hydrological context, the continuity equation in the form $dS/dt=I(t)-Q(t)$ (S storage, I input, Q output) and a function that relates the storage to outflow $S=f(Q)$ is used here where f is some non-linear function. We determine this function by relating reservoir storage S and outflow Q to the reservoir water level H, applying the so called level pool algorithm. In addition, we assume that the size A of the lake or reservoir is constant for any H and that the relation between Q and H is of the form $Q=a\, H^{b}$. We used a third order Runge-Kutta-scheme to solve the above differential equation (Chow et al. 1988). Since the size of the water bodies A is tabulated for the relevant lakes, only the two parameters a and b have to be estimated. We used non-linear optimisation procedure (quasi-Newton) to deduce them. Indeed, optimisation can only be used when input as well as output hydrographs are available. Bearing this in mind, we achieved the following Nash-Sutcliff-efficiencies for four Bavarian lakes: Ammersee: 0,990, Chiemsee: 0,993, Rottachsee: 0,955, Sylvensteinsee: 0,634. Of course, reservoirs like Sylvensteinsee where outflow is highly controlled by man cannot be modelled by considering the natural process of flood attenuation alone. To accomplish this, we are acquiring further data from the reservoir operators.

A very relevant part of the tasks of the surface water research group is generating sewerage systems of larger settlements and municipal sewage plants. For the time being, a comprehensive literature study has been made here in order to elaborate the construction rules for all relevant elements of sewerage systems.

In an interdisciplinary manner, the model components of the three research groups landsurface, groundwater and surface water were investigated together, resulting in some important insights concerning the interrelations. Beyond that, contacts especially to the tourist-, economy-, and household research groups were established in order to improve the interfaces.

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GLOWA-Danube

MODELING SNOW COVER AND GLACIERS WITHIN THE CATCHMENT AREA OF PASSAU-ACHLEITEN GAUGE

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Keywords: snow cover, glacier, energy balance, turbulent flux parameterization, surface temperature, validation

Abstract

Within the report period the work of the Glaciology Group concentrated on the improvement of the physics of the DANUBIA-component SNOW, which calculates the evolution of snow accumulation within the entire catchment area of the upper Danube basin on a grid length of 1 km. The Implementation of sophisticated algorithms to calculate the accumulation and more realistic parameterization schemes to determine the turbulent fluxes with respect to different land use improved the agreement of the distribution of the local snow cover compared with observations. An offline multiple layer model was developed to transfer the DANUBIA-calculated water equivalent of the snow accumulation to "real" snow heights, which enables local validation of the model results. In cooperation with the Danubia-atmosphere group a sensitivity study was carried out to test the realism of the output of the regional climate model MM5 near ground. As a first result, the agreement of modelled and observed meteorological data is widely improved compared to the first approach of the Phase 1 of the project.

Results

The snow model calculates snow melt based on an energy balance approach. The available energy for melt at the snow surface is determined as the residual of the sum of the radiation balance and the turbulent fluxes. Radiation balance is delivered by the module *Radiation balance*, which is coupled with the snow model at every time step. To estimate the turbulent fluxes of sensible and latent heat, a new parameterization bulk scheme is implemented derived by Weber (2004). It is based on the results of eddy correlation measurements which were carried out on the Vernagtferner (Austria) in summer 1998 and 2000. In contrast to the approach used up to now, its advantage is taking into account both the dependency of the fluxes on altitude above sea level and surface characteristics. Unknown surface temperature is calculated by an iteration process, which has been improved for a better numeric stability.

To enable the validation of the model results, a simple multi layer model was developed to take into account the settling of fresh snow and calculate the actual mean snow height at the proxel. This model may be implemented into DANUBIA´s SNOW-module in the future and then supplies helpful information to the actors e.g. tourism and others. At a first step it was used offline to compare the snow cover, modelled during the reference run, with local observations at climate stations.

The comparison, using the meteorological data created by *AtmoStations*, shows excellent agreement during the accumulation phase. If elevation of the climate station matches to the mean value of the Proxel, then both, dynamics and absolute snow heights, will be reproduced accurately. In contrast, ablation processes occur too fast, because of too much absorption of short wave radiation energy. This problem is hoped to be solved by the implementation of a more realistic algorithm to the decrease of the albedo with time according to Rohrer (1992).

To test the new parameterization of the near ground temperature of the MM5-modell a sensitivity study was carried out using parts of the snow-model. The results show a better agreement with the interpolated station data from previous runs. But there still remains a tendency to yield a temperature that is too high above snow covered areas at higher elevation. This deviation may depend on the fact, that the actual state of the surface is presently unknown to the MM5-model. Therefore energy loss caused by melt processes and consequently a stronger cooling of the surface layer is not taken into account. Improvement by stronger coupling of both models is an essential next step in the work plan.

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DATA-BASED QUALITY CONTROL REGARDING THE PRECIPITATION - LANDSURFACE INTERACTION

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Keywords: Atmosphere-object, meteorological observations, downscaling

Abstract:
The interaction between the atmosphere and the land surface is of great importance for the regional climate and plays a decisive role within the GLOWA-Danube project. The main task of 'Meteorology/Observations' is to provide high quality downscaling factors for AtmoMM5 and to perform a quality assurance of the model system DANUBIA with regard to the atmospheric parameters. In a first step we compared time series of precipitation and air temperature at several measuring sites with the respective proxel values resulting from DANUBIA to assess the accuracy of the employed method. Our results show that the root mean square error of the difference between AtmoMM5 and the observations is reduced as compared to that of MM5 – observations.

Results:
As a first step of the intended quality assurance a comparison of meteorological time series (1991-2000) of DANUBIA are compared directly to station measurements. In doing so, it is important to recall that the DANUBIA results are related to the proxel area of 1 km^2 whereas the measurements are representative for the stations only. As meteorological parameter we focused on the precipitation (P) and the air temperature (T). The observed time series (*Obs*) are compared to the results of the mesoscale atmospheric model *MM5*, the downscaled *AtmoMM5*, and the *AtmoStations* component of DANUBIA.
The employed settings of *MM5* were described in previous reports (see Meteorology/Modeling). Since the *MM5* resolution is coarser than the DANUBIA proxel grid the meteorological parameters need to be downscaled. The method employed for *AtmoMM5* is customized for each parameter separately. Its basis is a monthly climatology of measurements interpolated to the proxel grid. In case of P the climatology is constructed using the PRISM-algorithm (Daly et al., 1994) applied to the European Alps by Schwarb et al. (2001). The downscaling for P consists of 2 separate steps: First, the local subscale variability is inferred from the observed proxel climatology. Second, a bias correction is applied, which constrains the downscaled model climatology to be equal to the observed climatology on the coarse grid. Combining both steps results in a local scaling factor for each day of the climatological year (Früh et al., 2005).

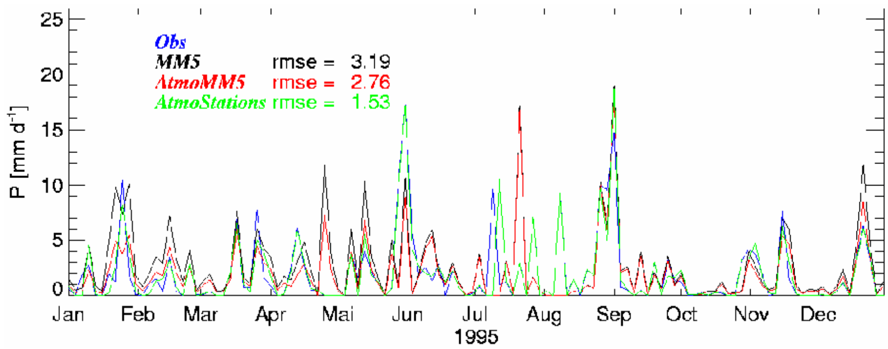

***Fig 1:** Precipitation in Regensburg (and resp. proxel) from the measurements (blue), the MM5 (black), the AtmoMM5 (red), and the AtmoStations (green) simulations in 1995.*

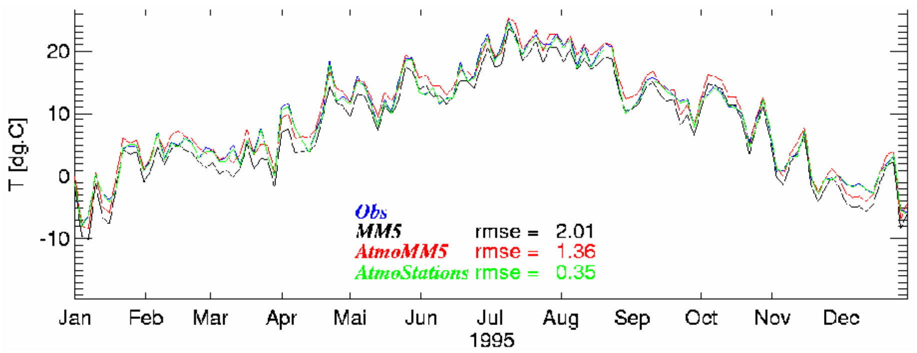

Fig 2: *2m-Temperature in Regensburg (and resp. proxel) from the measurements (blue), the MM5 (black), the AtmoMM5 (red), and the AtmoStations (green) simulations in 1995.*

Fig 1 shows that *AtmoMM5* closely resembles the P measurements in most periodes. In some periods (e.g. Jun) P is underestimated and in some (e.g. Jul) overestimated by the simulation. The downscaling leads to a reduction of the root mean square error of the difference (rmse) between the daily P of *AtmoMM5* and *Obs* as compared to that of *MM5*. The rmse of *AtmoStations* is low, as is expected, since the measurement is a direct input for the calculation.
The downscaling for T is similar to that of P except that the anomalies to the observed climatology are applied additive rather than multiplicative. Fig. 2 shows the results for T. *Obs* is reproduced by *AtmoMM5* very well and the rmse is reduced by the downscaling.

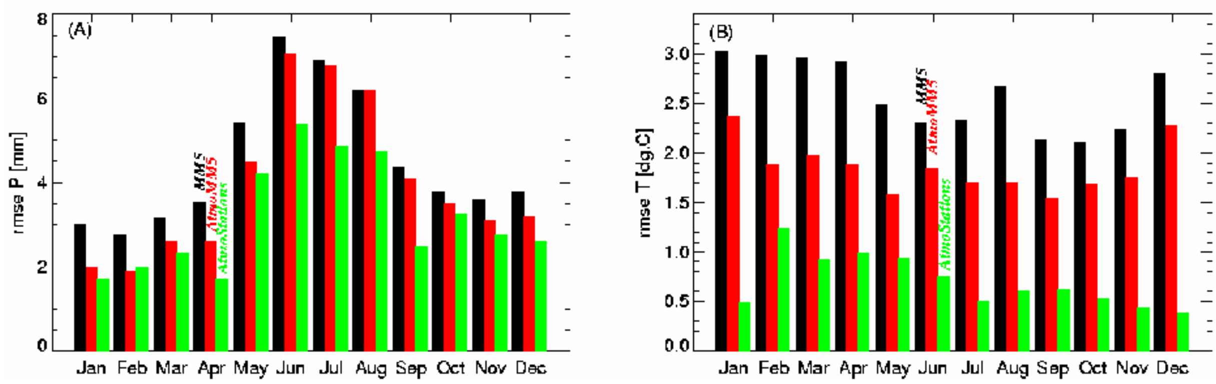

Fig 3: *Precipitation (A) and 2m – temperature (B) rmse of the difference between the daily P of Obs and MM5 (black), the AtmoMM5 (red), and the AtmoStations (green) in Regensburg.*

Fig. 3 (A) shows the seasonal dependence of the rmse of P. For all methods investigated rmse is highest in the summer months (May – Aug). This is due to the summerly convective P which is difficult to simulate. In *MM5*, the convective P is generated by subgrid-scale processes. In *AtmoStations* and the P climatology (basis of downscaling), the P measurements are interpolated to the proxel area smoothing the strong spatial variability common in convective events. The 2m-temperature rmse has a weaker seasonal dependence (Fig 3 (B)). The rmse of T is lower and the reduction due to the downscaling stronger as compared to the rmse of P.

	T [°C]		P [mm]	
	mean	rmse	mean	rmse
Obs	8,7		2,7	
AtmoStations	8,3	0,9	2,7	1,7
MM5	7,0	2,8	3,1	3,5
AtmoMM5	8,7	2,1	2,9	3,4

Tab. 1 contains T and P averaged over 5 stations (Regensburg, Augsburg, München, Garmisch-Partenkirchen, and Hohenpeißenberg). The mean values are in very good agreement with *Obs*. The downscaling reduces the rmse in case of T and P.

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METEOROLOGY: MODELLING THE ATMOSPHERE ON THE MESOSCALE

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Key Words: meteorological simulation, downscaling, landsurface-atmosphere interaction

Abstract:
The main task of 'Meteorology/Modelling' within GLOWA-Danube is to provide, to adapt and to operate the mesoscale atmospheric model MM5 and its integration into the interdisciplinary model DANUBIA. In this context further developments in the downscaling of precipitation have been made in respect to a possibly altered flow regime in a changing climate. Also deficiencies concerning downscaling of near surface temperature (detected in close cooperation with research group 'Glaciology') have been addressed together with research group 'Meteorology/Observations'. New data required by the groups 'Tourism' and 'Environmental Psychology' are now provided via the corresponding interfaces. Investigations in respect to the interactive coupling of MM5 to the landsurface model show the influence of the coupling time step and of the accuracy in the partitioning of modelled surface latent and sensible heat fluxes.

Results

-Flow-dependent downscaling

A changing global climate e.g. due to the increase of CO_2 might not only result in higher temperatures in the lower atmosphere and an overall change in precipitation amounts, but in altered flow regimes in central Europe as well. These flow regimes have predominant impact in the complex orography of the alpine region. For example effects like upslope precipitation depend profoundly on the actual flow. To reflect this in our downscaling technique, which so far was adopted to our present-day climate, we implemented the influence of the predominant flow into our scaling functions used to downscale the original MM5 (1, 2) output to the mandatory horizontal resolution of 1x1 km2 of DANUBIA. This was done by building classes of flow regimes and defining separate scaling functions for each regime. This procedure has no major influence when applied to present-day climate (and the underlying present-day flow regimes) as was expected. The correlation coefficients for modelled precipitation versus observed data reach already rather high values of up to 0.95 (3). So the substantial benefit of our currently applied downscaling functions is already obvious, yet the refined downscaling approach is essential in a changing climate

-Downscaling of near surface temperature

First validation runs of DANUBIA resulted in unrealistic intense accumulation of snow in the higher alpine regions. Analysis of this behaviour in close cooperation with research group 'Glaciology' revealed that this was due to unrealistic low values of the downscaled near surface temperature and too high daily amplitudes of temperature. This motivated a thorough redesign of the scaling functions for temperature together with research group 'Meteorology/Observations' which shows promising results in test runs performed in cooperation with group 'Glaciology'. The new downscaling procedure together with the newly constructed downscaling functions have been implemented in the atmosphere object and are ready to be used within DANUBIA.

-Additional work on AtmoMM5
The redesign of AtmoMM5 also comprised substantial optimisations in respect to numerical performance in compliance to the recommendations made by group ‘Computer Science’. This is of great value in the one way coupled as well as in the interactive mode of AtmoMM5.
Furthermore monthly and daily means and highest/lowest values of some variables as well as sunshine duration have been requested by groups ‘Tourism’ and ‘Environmental Psychology’ which now are provided via the corresponding interfaces.

-Interactive coupling MM5/landsurface
In the context of the landsurface-atmosphere interaction first of all the effects of the coupling time step between the two model parts representing atmospheric phenomena and the surface have been investigated in several sensitivity studies. A simulation of June 1995 in a fully coupled mode of atmosphere and landsurface served as a control run. Here the standard version of MM5 was used where landsurface-atmosphere interaction is calculated at every model time step of MM5 (130 seconds). These results were compared to runs where the atmospheric part had been decoupled from the landsurface routines. The surface sensible and latent heat flux as well as momentum flux now came from stored data from the control run and were coupled into the remaining atmospheric part of MM5 from an external file. This was done for a first sensitivity run every 10 minutes and for a second run every 60 minutes (which presently is the standard exchange time step in DANUBIA). It followed that both runs agreed rather well for a time step of 10 minutes, whereas substantial discrepancies showed up in the case of a 60 minutes time step with e.g. daily maximum and minimum near surface temperatures differing up to 3 Kelvin and with changes in near surface moisture of about 10 percent.
A second set of sensitivity runs addressed the partitioning of the total surface energy flux in sensible and latent heat (4, 5). The total amount of energy flux between land surface and atmosphere stayed unchanged compared to a control run, but a change of +/- 20% in the latent heat flux was induced, which was balanced by a corresponding change in the sensible heat flux. This approach reflects to some extent the calculations in the landsurface-object which gives the sensible heat flux as the residuum of the surface energy balance. Comparing near surface values of temperature and moisture we again found differences up to 3 Kelvin and 10 percent respectively. These findings give an idea about how carefully the surface energy fluxes and their partitioning need to be simulated .

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A METEOSAT-8 SEVIRI BASED RAINFALL RETRIEVAL FOR THE UPPER DANUBE CATCHMENT CONSIDERING CLOUD PROPERTIES

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Key Words: rainfall retrieval, cloud property retrieval, optical satellite sensors

Abstract
The integrative aim of this project is to make available high-resolution rainfall information for the DANUBIA Landsurface, Rivernetwork and Actors packages. In addition, the data is used to evaluate the overall performance of the AtmoMM5 and AtmoStations-derived precipitation fields. To this end the modular Advective-Convective-Technique (ACT) has been developed and implemented in the operational processing chains at the LCRS. The resulting rainfall products with a temporal resolution of one hour are provided to DANUBIA by the AtmoSat module, which is part of the Atmosphere package. Two of the three ACT modules use only data from one water vapour and one infrared channel available on both Meteosat VISSR and SEVIRI. Therefore these modules are suitable for the investigation of long time series processed from 1995 until today. The third ACT module benefits from the increased spectral resolution of Meteosat-8 SEVIRI with the potential for cloud optical and microphysical property retrievals. The scheme was validated against DWD radar data and a comparison with precipitation fields derived from AtmoStations and AtmoMM5 shows good agreement.

Results
The Advective-Convective-Technique (ACT, Reudenbach et al. 2005) has been developed to compute a satellite-based precipitation product for the period from 1995 to today using Meteosat VISSR and SEVIRI data with a temporal resolution of 30 and 15 minutes respectively. The hourly aggregated rainfall is supplied to DABUBIA via the *AtmoSat* module.
Since the VISSR and SEVIRI sensors differ significantly with respect to their spectral resolutions, the ACT was designed as a modular retrieval. While two modules identify precipitating cloud regions using only one water vapour (WV) and one infrared (IR) channel available on both sensors, the third module takes advantage of the increased spectral resolution of Meteosat-8 SEVIRI leading to a more reliable identification of stratiform raining clouds with warm and homogeneous cloud tops.
The module for the identification of convective precipitation is based on the Enhanced Convective Stratiform Technique (ECST, Reudenbach et al. 2001) that uses positive TB_{WV}-TB_{IR} differences (*DWI*) in order to discriminate between deep convective, optically thick clouds (*DWI*>0) and non-raining cirrus (*DWI*<0, cf. Tjemkes et al. 1997). A second module detects rainfall areas in warm frontal systems by an iterative k-means clustering analysis based on TB_{IR} and TB_{WV} data and a 3x3 pixel TB_{IR} standard deviation (*StdvIR*). The resulting clusters represent stratiform raining clouds if the maximum TB_{IR} and *StdvIR* of the cluster are below or above specified thresholds. The assignment of the rainfall rate relies on idealised 3D cloud model runs with the mesoscale Advanced Regional Prediction System (ARPS, Xue et al. 2003). For the adjustment to the upper Danube catchment, ten years of radiosonde data over central Europe were analysed yielding a representative set of precipitating profiles (see Reudenbach et al. 2001).
A comparison between the three precipitation products of the DANUBIA *Atmosphere* package and an evaluation against DWD radar network data for the time period from 1995 to 1999

reveal better performance of the *AtmoMM5* and *AtmoStations* products during advective/stratiform rainfall events where *AtmosSat* is based on data from the WV/IR channels alone. For mainly convectively induced precipitation, the *AtmoMM5* product is limited by the well-known uncertainties in the cumulus parameterization schemes of mesoscale models. *AtmoStations* shows a tendency to overestimate the area of convective precipitation patterns and therefore the average amount of rainfall based on the spatio-temporal interpolation of the rain gauge point measurements within the catchment. On the other hand, the satellite data of *AtmoSat*, updated at half-hour intervals, allows for a more precise monitoring of rainfall dynamics and an accurate identification of convective cloud regions (Reudenbach et al. 2005).
Since the end of the Meteosat-8 commissioning phase in 2004, SEVIRI data is received at the LCRS and the ACT is computed on a 15-minute basis, also using the most recently developed third module. Nevertheless, the described WV/IR channel modules are still applied to every data set to continue the homogeneous time series started in 1995 (Nauss et al. 2005a). The precipitation product using the third ACT module is computed taking into account additional information of cloud optical thickness and cloud effective droplet radius. The identification scheme is based on the concept that potentially raining cloud systems require both a minimum optical thickness and a minimum effective cloud droplet radius (cf. Lensky et al. 2003). The cloud parameters are retrieved by the semi-analytical and therefore fast computing SACURA approach, which is based on approximated solutions of the asymptotic radiative transfer theory, showing excellent correlation to commonly used but computer-time-expensive look-up table approaches (Kokhanovsky et al. 2003, Nauss et al. 2005b). Results of a validation study comparing 250 satellite scenes between January and August 2004 with data from the DWD radar network indicate a significantly increased accuracy of the derived rainfall product comparable to ground based radar measurements. This time, advective/stratiform events, which were problematic to retrieve by using the WV/IR modules only, were taken into account.

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GLOWA-Danube

MODELLING THE IMPACT OF AGRICULTURAL LANDUSE CHANGES AND MANAGEMENT METHODS UPON WATER-, NUTRIENT- AND CARBON-FLUXES

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Keywords: integrated modelling, plant growth, water use, biomass production, water use efficiency, impact assessment, Danube river basin, transpiration, nitrogen fluxes

1. Organisation

The project "Agricultural Ecosystems" entered the GLOWA-Danube research group on March 1, 2004. Due to the differences in modelling agricultural plants as compared to natural ecosystems, the different requirements with regards to the interaction of the model components within DANUBIA, and due to the unique expertise of each group, the biological modelling tasks were split in the current project period into *agricultural ecosystems* (Cologne) and *natural ecosystems* (Bayreuth). The project funds 3 BAT IIa/2 researchers and is supported by two researchers (Prof. K. Schneider, Dr. P. Fiener) through basic department funds.

2. Project Tasks

As part of the *DANUBIA* decision support system, the subproject *agricultural ecosystems* is developing a spatially detailed, meso-scale growth model for agricultural plants and a nitrogen turnover model. These models are part of the components *Biological* (plant growth) and *Soil* (nitrogen turnover). Both models are of key importance to quantify the impact of climate change and changes in agricultural use upon water-, nutrient- and carbon-fluxes. The main tasks of the project during the first project phase were:

- to become acquainted with the existing DANUBIA framework,
- to further develop interfaces between *Biological* and the DANUBIA components of the project partners particularly with *LandSurface* and *Farming*,
- to further develop and improve agricultural plant growth models particularly for wheat, barley, corn and grassland,
- to develop a nitrogen turnover and plant uptake model for DANUBIA,
- to develop a validation strategy for the model components and to provide suitable validation data.

3. Results

The primary goal of becoming acquainted with the complex DANUBIA framework was achieved in a short time frame. With the introduction of the new test-framework in October 2004, the project group was able to test the existing model components, to extend the interfaces with other DANUBIA model components, to improve the model performance with respect to agricultural plants and to participate in the development and analysis of DANUBIA model runs. In order to quickly participate in integrated modelling exercises within DANUBIA, the focus of our research was put on improving the existing modelling approaches instead of developing new model components. DANUBIA uses a process based plant growth model, which accounts for photosynthesis, transpiration, respiration, allocation and senescence. To provide suitable input data particularly for the model *Farming* the allocation of agricultural plants was revised and enhanced.

UML diagrams for an improved plant growth model and for a nitrogen turnover model were developed. Based upon these diagrams and in cooperation with the project partners, new model components are currently under development using existing and well tested modelling approaches. These model components will improve the allocation to plant organs as well as the modelling of growth stress and senescence. A nitrogen turnover and plant uptake model, which calculates nitrification, denitrification, mineralisation, immobilisation and hydrolysis was developed for DANUBIA and is currently being tested.

To provide suitable data for further model development and validation, measurements of vegetation and nitrogen parameters were acquired from various sources and additional measurements were conducted. Measurements of plant parameters (LAI, biomass of leaf, stem, grain, C- and N-content, phenology, sap flow), photosynthesis (using a *PP-Systems Photosynthesis system*), spectral reflectance (*ASD-spectrometer*), and soil nitrogen content were conducted for various agricultural uses. A *Campbell Eddy Covariance* system, Bowen ratio system as well as a sap flow system were successfully installed and tested. Based upon our measurements, relationships between spectral reflectance properties (NDVI) and LAI were successfully validated for various agricultural uses and newly established for sugar beet. This analysis is a basis for assimilating remote sensing data into DANUBIA. Analysing three LANDSAT TM images from 2003 provided evidence of the impact of water stress on plant growth. Comparisons of model results (biomass, LAI) and measurements showed the suitability of the improved model to calculate plant growth for a range of agricultural land uses (corn, summer barley, winter wheat, meadows). The model results obtained with the test-framework compare very favourably. The results with DANUBIA showed significant improvements as compared to earlier model runs. However, due to the manifold interactions and feedbacks of DANUBIA, the results are currently less favourable than the results obtained with the test-environment.

4. Plans for next year

While further improvement of the models will be an ongoing task, work in the upcoming year will focus particularly on the extension of the models with respect to the previously mentioned components (allocation, stress), addition of other vegetation types (sugar beet, potato) and the development and test of a nitrogen turnover and plant uptake model. Scaling issues from the field-scale to the meso-scale will be investigated particularly with respect to nitrogen turnover. Among other measurements, eddy flux measurements will be conducted on a sugar beet field to provide currently lacking validation data. Multi-scale model validation using field measurements, agricultural statistics and model comparisons will be carried out.

5. Publications

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6. Conclusions

Despite the demanding tasks of seamlessly joining an ongoing project and mastering the complex technology developed and used in the research group, all of our proposed plans and our workload of the first year were achieved and our research group has become a productive member of the GLOWA-Danube research network.

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GLOWA-Danube

INFLUENCE OF THE VEGETATION ON WATER AND CARBON FLUXES AND ON PRODUCTIVITY OF DIFFERENT VEGETATION TYPES IN THE GLOWA-DANUBE BASIN

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Keywords: Ecosystem fluxes, water and carbon balances, growth and production, up-scaling, mountain gradients, forest, wetlands, mountain grasslands

Abstract

The Biological-Object of DANUBIA has advanced in terms of parameterization in agreement with field studies to provide regional estimation of vegetation/atmosphere gas exchange, grassland and crop growth and, thus, water and carbon balances. Up-scaling studies are reported that aid calibration at 1 km² scale and in complex mountainous terrain of the Danube catchment. Additionally, the Biological-Object has been expanded to increase capacity for simulation of production processes in both "near-natural" ecosystems (forests, wetlands and alpine meadows - Univ. Bayreuth) and agricultural ecosystems (multiple crops with intensive management - together with Univ. Köln). Parameterization must be completed along elevation gradients, with different exposure and for low soil water availability.

Integrative Development of the *Biological-Object*

In order to increase the depth of coverage for natural ecosystem processes and to include greater expertise with respect to agricultural management practices (provide for the needs of the agroeconomic module), the *Biological-Object* of DANUBIA developed by the Univ. of Bayreuth during Phase I of GLOWA-Danube is being expanded in an intensive cooperation with the Univ. of Köln (group of Prof. K. Schneider) to provide the new components diagrammed in Fig. 1. The new *Biological-Object* runs in a DANUBIA test framework that is common to both research groups. Substitution of the new object for the current Univ. Bayreuth version within DANUBIA is planned for summer 2005.

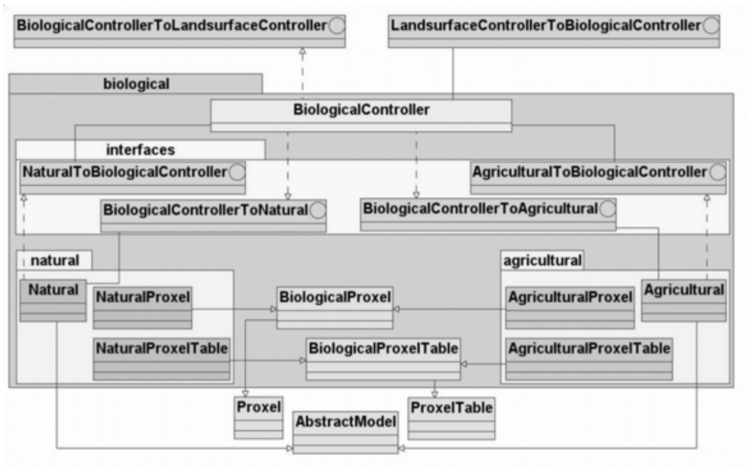

Fig. 1. UML-Diagram showing the new Biological-Object and sub-structure for Natural and Agricultural ecosystems and their coordination with a BiologicalController.

Parameterization of the Biological-Object in DANUBIA

Parameterization of the Biological-Object has first been carried out in relation to ecosystem studies at sites where fluxes are monitored via eddy-covariance methods and where growth and other processes are measured (Phase I research). To include the response of ecosystems along elevation gradients, further work was required. Thus, a detailed flux and growth model PIXGRO was developed for the GLOWA-Danube test site in Stubai Valley and applied at two scales: 100 m pixels that correspond to the scale of field studies and 1 km pixels that correspond to representation in DANUBIA. An overview of results estimated for the spring through fall seasons in 2002 is given in Table 1. Scaling influences were small in the absence of water stress and except at higher elevations where temperature response seems to be sensitive (further study is required).

Table 1. Results from simulations with the flux and growth model PIXGRO applied at 100 m and 1 km resolution in Stubai Valley. Data provide the best source for calibration of the Biological-Object in DANUBIA when considering complex influences of mountainous terrain. PIXGRO was validated based on field studies in Berchtesgaden and in Stubai Valley (see previous reports and Kolcun 2005).

Resolution:	100 m		1 km		Change with scales: 1km/100m			
	Et	Tr	Et	Tr	Δ%	Δ%	Δ%	Δ%
Land use or ecosystem type	(mm)	(mm)	(mm)	(mm)	Et	Tr	GPP	R_{eco}
Montane coniferous forest	168	77	168	76	0	-1	-2	-5
Subalpine coniferous forest	142	49	149	44	5	-10	-10	-7
Very intensive meadow	270	123	275	124	2	1	-2	1
Intensive meadow	236	88	222	82	-6	-7	-3	-4
Extensive meadow	225	85	246	96	9	13	8	11
Abandoned meadows	214	89	214	71	0	-20	3	2
Alpine mats	239	92	225	69	-6	-25	-2	-3

Et = evapotranspiration; Tr = transpiration, GPP = gross primary production, Reco = ecosystem respiration

Examination of the results of the most recent DANUBIA reference simulations (various sites with different local climate and exposure) and those from PIXGRO simulations in Stubai Valley (Fig. 2) show that canopy transpiration (Fig. 2A, C, D) and GPP (Fig. 2B) of low elevation grasslands and coniferous forest compare well in magnitude and have appropriate sensitivity to environmental factors. An improvement must be achieved in the representation of water use by vegetation along the elevation gradients in the Alps (cf. Fig. 2C), especially at high elevation.

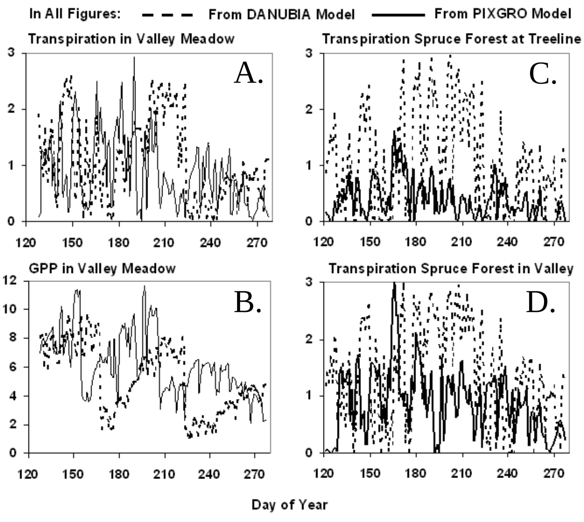

Fig. 2. Comparison of canopy water flux (mm day^{-1}) and GPP (g C m^{-2} day^{-1}) estimated by DANUBIA and by the detailed process model PIXGRO which is calibrated to field measurements in the GLOWA-Danube test sites of Berchtesgaden and Stubai Valley. Dashed lines are DANUBIA, solid lines from PIXGRO. Different mowing regimes are apparent.

Challenges

Continuing work during 2005/2006 focus on completion of the new Biological-Object as in Fig. 1, completion of parameterization, especially along elevation gradients and in response to reduced soil water availability, and beginning the implementation of growth routines for forests (currently only grasslands and crops grow in DANUBIA).

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GLOWA-Danube

SOCIO-ECONOMIC ANALYSIS AND MODELLING OF AGRICULTURAL LAND AND WATER USE

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Keywords: Optimisation model, disaggregation, farming decider, agriculture, land use

Abstract

To analyse and evaluate the effects of Global Change scenarios on agricultural land use and water demand in the context of the integrative decision support system DANUBIA is the task of this project part. A regional economic optimisation model was developed that calculates farmer's land use plans for the next vegetation period every year. These district based modelling results are distributed on each proxel by a disaggregation tool. To model farmer's daily decisions in cultivating arable land and grassland on the basis of the results on land use of the regional economic model a so called farming decider is under development. The concept of the farming decider can be regarded as a preliminary stage for the "Deep Actor" and will be transferred to the "Deep Actor" framework in the future. However, the farming decider enables a close connection of agricultural and natural science parameters for practical cultivation activities within DANUBIA. Statistical data was processed for the GLOWA Atlas and new land use data for the DANUBIA database.

Results

The component of the agro-economic group within DANUBIA consists of three moduls: a district-differentiated, comparative-static regional optimisation model that calculates farmer's plans for the next vegetation period on a yearly basis (RÖHM & DABBERT 2003, KRIMLY et al. 2004); a disaggregation tool that distributes the regional results on proxel level and a farming decider that realises farmer's land use plans by modelling daily cultivation practice depending on natural conditions.

The regional economic model was upgraded for the Austrian part of the Upper Danube catchment. Furthermore, data output of the amount of organic and mineral nitrogen (N) and phosphorous (P_2O_5) fertiliser and of extensively and intensively used grassland for each district was formulated. The distribution of extensively and intensively used grassland on each proxel and the Austrian part of the catchment area was added to the disaggregation tool. A first concept of the farming decider was developed to realise farmers land use plans resulting from the regional economic model. So far the farming decider contains farmer's decisions on the specific date and input of N and P_2O_5 for each crop/grassland on proxel level. Therefore, the catchment area was classified in different climate zones (KTBL 2003) and a time period to practice the fertilisation activities was defined for each climate zone. The farming decider interacts with "landsurface physical" that delivers data on soil temperature and soil saturation which determine the possibility to apply fertiliser on the field. The farming decider concept can be regarded as a preliminary stage for the "Deep Actor". It will be transferred to the "Deep Actor" framework in the future.

Furthermore, data was processed for the GLOWA Atlas on the one hand and the DANUBIA database on the other hand. Statistical data on farm size, number of cattle and pigs and the livestock unit on district level were processed for the GLOWA Atlas to depict the structure of agriculture in the Upper Danube catchment (WIRSIG et al. 2005). As already mentioned in former reports the land use data on arable land and grassland which are applied in the DANUBIA database differ widely from the statistical data in 1995. Due to the fact that the agro-economic model is calibrated on these statistical data the model results can not be interpreted. The new land use classification of the central project is not finished yet. Therefore, it was decided that the agro-economic group develops a new land use classification which is calibrated on statistical data. The classification which is based on statistical data on district level and CORINE land cover (250 m^2 Pixel) was generated in November 2004. So far this new land use classification was not implemented in the DANUBIA database. As a consequence the results of the agro-economic model can still not be interpreted.

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Project ID: 01LW0303A ("Environmental psychology")
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GLOWA-Danube

MODELING OF TYPICAL DOMESTIC WATER CONSUMERS IN THE UPPER DANUBE BASIN

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Keywords: water use, actor based modeling, risk perception, acceptance of political measures

Abstract:
After numerous data have been collected during the first phase of GLOWA-Danube and a first version of a shallow model of domestic water use has been constructed, (1) there have been numerous extensions to the shallow model and extensive validation against empirical data allowing to run meaningful integrated scenarios, and (2) a deep agent-based model including a detailed description of the micro-behavioral decision processes of the households has been conceptualized, designed and is being implemented in close collaboration with the computer science group of GLOWA-Danube. The agent-based framework will serve as basis for the implementation of further actor models of other groups within GLOWA-Danube.

Results:
The household model reflects two modes of behavior by two behavioral layers. A shallow model layer implements the empirically observed strongly habitual water use of the agent. A so-called deep model layer reconstructs the process of water-related decision making when adopting water saving technological innovations. Both layers live side by side in the household model.
(1) Extensions to the shallow model. Some empirical characteristics of domestic drinking water use as found in our data and from the literature have been already implemented in phase I: (1) Wealthier households have a tendency toward a higher per capita water demand, probably also due to a larger number of water using appliances. (2) However, drinking water seems to be price elastic only to a small extent. (3) The larger the household, the smaller the per capita water demand, due to e.g. savings through the more efficient use of dishwashers. The following are the extensions to the model implemented in the current phase: (4) There are clear seasonal dynamics, resulting in a higher water demand in summer due to e.g. more showering. (5) There has been a steady decline in household water use since the 1970s because of technological innovations (washing machines, toilets, dish washers). (6) The larger the agglomeration where the household is located, the higher its per capita water demand. This might be due to a relative difference in household structure and subsequently to a different lifestyle.
The computational steps of the shallow model are: (1) For each of the 25 household types, the water demand for 10 types of water use (e.g. shower, laundry machines, etc.) is computed on the basis of the empirical data. (2) Some of the water uses (shower, taking baths) are subjected to seasonal changes in the summer months depending on the simulation's current temperature. (3) Changes in water prices are included through a slight price elasticity of –0.3. (4) The resulting figures are aggregated to reflect the water demand of each of the 25 household agents. (5) Depending on the number of people living on a proxel, the water demand is corrected for the influence of the population density (see above). (6) In the same manner, a baseline of innovation and thus a slight reduction of water demand in every time step is taken into

account. (7) The total water demand for one proxel then is the result of the individual water demands of each of the 25 household types multiplied by the number of households of each type per proxel. (8) To reflect the demand of public buildings, 8% per proxel are added to the total demand.
In sum, the model produces a slight average water demand overestimation of about 1% compared to the reference statistic of the year 1998, including all inhabited proxels.

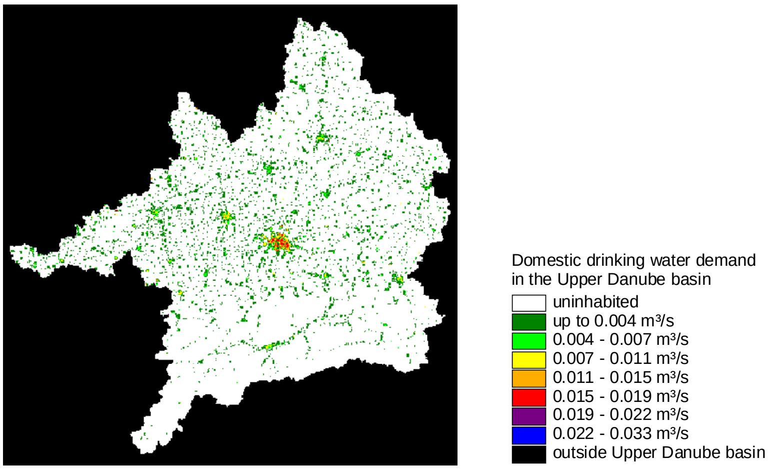

Fig. 2: A map of the drinking water demand in the Upper Danube river basin as modeled by the shallow household model in DANUBIA.

Besides the drinking water demand (and subsequently the waste water quantity produced by the households), water related satisfaction is derived from the drinking water allocated by the model "water supply companies" for the specific proxel. If the demands exceed the allocation, the water related satisfaction diminishes.
(2) Conceptualization, design, and implementation of the deep model. In order to allow for more complex decision processes within the agents of the actors component in DANUBIA, a generic framework for all actor models has been conceptualized, designed, and implemented together with the computer science group of GLOWA-Danube. Specific sensors relating to proxel information, to other actors, and also to simulated legal constraints, lay the ground for the decision algorithms to be defined by the specific actor model implementing the framework. Decisions are made about the choice and instantiation of plans, themselves being chains of more specific actions.
The "deep household" model, as one of those specific implementations of the framework, reconstructs deliberate decisions concerning e.g. buying a water saving shower head or taking baths. Relevant parameters include the behavior of other actors in the agent's network, the price, environmental issues of the behavior, habits, and the personal history of the agent. The networks are determined by one of 10 lifestyles, in which the modeled households are classified. This classification relies on fine grained spatially referenced data acquired from a commercial market research enterprise.
Publications since 3/2004 (end of phase I): Publications see below, plus six refereed conference presentations and invited talks, also international.

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GLOWA-Danube

DEVELOPING THE REGIONAL ECONOMIC MODEL RIWU INTO A "DEEP" ACTORS MODEL

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Key words: Natural Resource Economics, New Economic Geography, Regional-Economic Model, Industrial Water Use, Integration Approach, Global Change

Abstract

The economic research group has developed three different models: the regional economic model RIWU which calculates economic development and industrial water use, and linked to this, a demographic model to subdivide the population, generated in RIWU, into five classes of incomes and household sizes as well as an independent model to estimate the drinking water prices for households. Having developed these models for Germany, their methods now have been expanded to the Austrian and Swiss part of the catchment area. Furthermore the RIWU equations were updated to the state of research. This improved the models forecast quality and introduced the ability to react to water shortages. The drinking water price model has been retained basically unchanged; ex post forecasting and thus the adaptation to real drinking water prices was improved. The demographic model was modified in some details but also basically stayed unchanged.

Results

Having developed a basic regional economic model in the first phase of the project, in the first part of the second phase the up-to-date theoretical fundamentals of regional economics have been integrated in the model. In the theory of New Economic Geography, regional concentrations of economic activities are the result of an interaction of centripetal and centrifugal forces. The centripetal effects of agglomeration are mainly the result of the size of the local market that makes production with economies of scale possible. The centrifugal forces result from costs of agglomeration, which restrain growth. Examples of this are immobile factors of production like land or natural resources as well as negative external effects. In empirical models of New Economic Geography, prices for housing are the main forces that spread economic activities, for in their centres the demand for housing space is higher and accordingly more expensive. Within RIWU prices for living and water affect urban and industrial spreading. The price for building land is used as an indicator for the costs of agglomeration. In line with the project specifications, costs for industrial water use are introduced as the second limiting factor. As with land, water is also used as a local input factor. Economic growth and industrial water use now only depend on factors of supply and not as previously on local exports. Furthermore, in the modified model, proximity of the single administrative districts is taken into account. For it is assumed that economic change of an administrative district causes externalities on neighbouring districts.

In the thus far developed RIWU model, it is assumed that there is always enough water to satisfy industrial water demand. To be able to react to water shortage in a calculated scenario, it is necessary to broaden the model with a second calculational step: if there is water shortage on at least one proxel of an administrative district – this means the industrial demand is higher than the usable water supply – it is necessary to recalculate the model equations. For this, the price for industrial water use is increased as long as the resultant water demand matches the real supply. This has negative effects on economic development, gross domestic product, population, and household income in the affected administrative districts. Since for these variables the values of both calculations are saved, it is possible to measure the effects of water shortage on the economic development of the catchment area. This fundamental approach is to be enhanced by introducing the "deep" actor "industrial enterprise". A corresponding feasibility study has been successfully made during the development of the general new deep-actor framework.

The basis for the upcoming scenarios, a "wet" and a "dry" one, provides a reference calculation of DANUBIA which simulates the period from January 1995 to January 2000. With the monthly timing device of the economic models, the results are 61 points of calculation. For the economic research group, the reference calculation was successful. The realised results are in accordance with the results of the internal tests with the new test environments developed by the informatics research group. The exchange of the calculated data with the other components succeeded too, both input and output data. The models of the economic component are thus prepared for the calculation of the two scenarios.

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RELATIONSHIP BETWEEN WATER AS A RESOURCE AND TOURISM

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Keywords: Integration approach, ecosystems, socio-economy, scenarios, global change, tourism, touristic use of water

Abstract:

The aim of the tourism research group is to explore the importance of water as a resource for tourism. Two different aspects have to be considered. On the one hand, water is a factor concerning the attractiveness of a tourist destination, because it can be used for a variety of sports and leisure activities. Furthermore, areas covered with water or shorelines function as background scenery for tourism. Hence, the availability of water affects tourist demand. On the other hand, water is used for running tourist services. The focus of attention is on the water demands of the tourist superstructure and also of the tourist infrastructure. To estimate the tourist water demand, this research group is especially interested in skiing areas using artificial snow, golf courses and baths which have been geocoded throughout the research area. The specific water demand of these infrastructure facilities has been integrated into the DANUBIA model.
In the end, this model should act as a "deep" actor, able to make distinctive decisions based on its perceptions of the surrounding environment. In the next step, these decisions have an effect on tourism itself and also on the environment, especially on the water balance in the research area. A model of tourist attractiveness will also be established. The main steps during 2004 were to develop the concepts of a deep-actor model and a model of tourist attractiveness.

Results:

In the tourist industry, water is used in different ways, e.g. in accommodation facilities or for artificial snow machines. For the quantification of the water use, however, there are no statistics on which research can be based, thus leading to the necessity of making our own calculations. Currently, there is a flat actor model used in DANUBIA to quantify the tourist water demand in the upper Danube catchment area. The actor model of the tourism research group relies on a supply side view. This means that the focus is on the suppliers of tourist services and the amount of water they need. The actors (=tourist service suppliers) have a distinctive demand for water, depending on the type of infra- and superstructure. Currently, the focus is on the tourist use of drinking water.

The base of the tourist model is formed by the flat model component, which calculates the individual water demand of the infra- and superstructure. The expression 'flat' means the actor model is not actually capable of making its own decisions, contrary to the goals of the second phase of GLOWA Danube, as will be explained later. To estimate the tourist water demand, the needs of golf courses, baths and skiing areas using artificial snow were taken into account (Schmude/Sax, 2003, p. 8). It was therefore necessary to investigate and geocode these facilities. In combination with the specific temporal water demands, it was possible to quantify the water demand of the tourist infrastructure in both spatial and temporal respects.

The demand for water by the tourist superstructure (e.g. in accommodation facilities) had to be considered as well. Therefore, two sub-models were integrated in the supply-side oriented actor model. The first deals with the segment of overnight tourism, the other with the segment of day tourism. The purpose of these sub-models was to represent the frequentation of the accommodation facilities, which also leads to a certain water demand.

The sub-model ‘overnight tourism’ is based on data from the official accommodation statistics of Germany, Austria and Switzerland, providing information about overnight stays for each community on a monthly basis for the years 1995 until 1999. To analyze the trend in overnight stays on an annual basis, the research group collected data for the years 1984 to 2003. Time series analysis was calculated for each community in the research area. Therefore, an extrapolation of the evolution of tourist demand until 2005 could be calculated for every municipality in the research area. The results from the time series analysis were also needed for further enhancements of the tourist model. Furthermore, all the available beds in the communities were also integrated in the model. The water demand of an overnight stay was subdivided into a constant and a variable share. The constant share was linked to the number of beds available, and the variable share was caused by the visitors. The summation led to the water demand of the overnight stays. To meet the goals of DANUBIA based on the proxel concept, it was necessary to downscale the data. This was done by assigning the statistical data to populated proxels according to the share of the population in the community.

The sub-model ‘day tourism’ calculated the water demand of day tourists per proxel. Downscaling data was achieved as mentioned above. This sub-model was based on studies by Harrer (1995), who published ratios between day tourism und overnight tourism for Germany. The review of certain studies provided information about important activities of day tourists. The percentage of day tourists performing these activities was also acquired. By linking the activities of day tourists with specific water demands, the entire water demand of day tourists was calculated.

The summation of the water demands of tourist infrastructure, sub-model ‘overnight tourism’ and sub-model ‘day tourism’ led to the overall tourist demand for drinking water in the German, Austrian and Swiss communities of the research area, as shown in the reference run. The results of this run showed plausible values.

In advance of the future deep actor model a basic reaction algorithm based on data delivered through the interface to the WaterSupply model was integrated. In case of water shortage, the difference between water demand and supply was economized. New interfaces to other models were also implemented.

Furthermore, concepts for the realisation of a deep actor model and a supply-side oriented model of tourist attractiveness were formed during 2004.

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HUMAN CAPACITY BUILDING

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Keywords: Stipends, Technology Transfer, Emerging / Developing Countries

Abstract
The goal of the sub-project "Human Capacity Building" is to provide highly qualified young scientists from emerging and developing countries with the opportunity to enhance their knowledge while pursuing a M.Sc. degree in Stuttgart. Moreover, students from different countries are to be given the opportunity to discuss specific issues pertaining to the effects of global change on the hydrological cycle in an interdisciplinary setting involving the different research groups of GLOWA Danube. Thus a transfer of knowledge to emerging or developing countries is ensured.

Results
The M.Sc. program WAREM at the Universität Stuttgart begins annually in September. Hence, the new students are still participating in the preparatory semester, especially designed to get new students started in the M.Sc. Program WAREM. Currently, two students are supported with stipends: Ms. Joanna Studzinska from Poland and Mr. Ahmet Baran Özcan from Turkey. A third and possibly a fourth stipend will be awarded to the top students emerging from the preparatory semester. Thus students are encouraged to perform well in their studies.
During the report period, four scholarship holders finished their M.Sc. theses and / or submitted an independent study (see References). While some of the reports directly contributed to GLOWA-Danube, others are more loosely linked, showing that a broad range of knowledge has been obtained by the students.

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