GLOWA-DANUBE

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integrative techniques, scenarios and strategies regarding global changes of the water cycle

Case study: Upper Danube Catchment Area

a project
within the framework of
***GLO*bal Change of the *WA*tercycle (*GLOWA*),**
an initiative of the German Ministry for Research and Education (BMBF)

conducted by the
Danube Competence Network

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Starting Point

The scientific analysis of Global Change is characterized by a multitude of sectoral work in diverse research disciplines which have set global aspects as the center of their research interests. Global Change is therefore characterized by a network of interactions, in which man himself acts as the cause, is acted upon, and is the mediator. Due to the regional character of the political and economical spheres of influence, these changes have regional roots and causes. A prerequisite for a sustainable development and management of these natural resources is the possibility to plan and act with foresight. A system is considered sustainable if problems and conflicts are not shifted spatially, temporally, nor between these contextual dimensions. To accomplish this, the required straightforward, strategic and political concepts must be based upon farsighted analysis and evaluation of the interactions in the natural system, as well as in the relationship between man and nature. Farsighted analysis and evaluation requires the availability of suitable tools, which enable the prognosis of various possible future states in a deterministic manner and under consideration of all important natural and anthropogenic impacts. Thus, these impacts can be evaluated and alternative management plans can be developed.

The conflict of interest between water demand and availability, with respect to water quantity as well as quality, has lead to manifold technical and cultural solutions. However these solutions will be increasingly stressed in the near future, globally and regionally, by increasing population figures, changes in use and escalated conflicts over use, even to the extent that they will be pushed to or over the limits of their capabilities. The interaction between mountain areas as water suppliers and foreland areas as water consumers is an archetypical example of this. This interaction plays an outstanding cultural and economical role worldwide and can be found in different distinctions all over the world (e.g. Alps, Pyrenees, Himalayas, Andes, Caucasus Mountains, Ethiopian Highland). A central element of the integrative global solution approach within the framework of GLOWA is to understand and explain this interaction.

With present capabilities, mountain areas and their forelands cannot be described and analyzed in integrated models, with the necessary accuracy required for forecasting, due to the complexity, sensitivity and high degree of integration. Yet, just this is needed in these areas to determine the sustainability of various management alternatives under changing boundary conditions and to derive appropriate recommendations.

Therefore, within the framework of the GLOWA-DANUBE project and based on the GLOWA call for proposals (see www.gsf.de/ptukf/glowa-e.pdf), a tool in the form of a Decision-Support-System to determine water fluxes, its coupled fluxes of matter, and matter turnover shall be developed, validated and applied exemplarily to an alpine catchment of the temperate latitudes. The chosen case study is the Upper Danube.

Project Goals

The overall goals (differentiated for the total intended project length of a planned eight year period as well as for the first project phase) of the GLOWA-DANUBE project are:

1. for the functional type of a catchment in mountain forelands of the humid latitudes (F2, see Call for Proposals for GLOWA): To develop and validate integration techniques, integrated models, and integrated monitoring procedures and to implement them in the network-based Decision-Support-System DANUBIA. Based upon the experience derived with these applications, they will then be refined. DANUBIA should contain the essential physical and socio-economic processes that are required for realistic modeling of water fluxes in mountain-foreland situations. Above all, the lateral flow, the relationships between the upper and lower river sections, the meteorological gradients as well as the

special use of sensitive boundary areas will be taken into account. It will be regionally transferable and thus applicable for the wide range of catchments within the GLOWA transects.

In the first project stage, DANUBIA will be set up as a prototype of a network-based integrative scenario tool. Its operative readiness will be shown with various scenarios, that also contain the actual state. Using new networked modeling technologies opens new possibilities of integrating various disciplines. In a second step, the system will be refined by taking into account the regional interest groups and agents.

2. to exemplarily apply DANUBIA with respect to the entire range of topics of the Global Change of the water cycle (GLOWA) in the whole Upper Danube catchment regarding the actual state, and to develop various future scenarios and investigate these with regards to their sustainability. Through the best possible realistic simulation of future scenarios, it is intended that DANUBIA deliver the basis to evaluate management alternatives concerning a foresighted water management and sustainable development of the fluxes of water and matter at regional scales under consideration of global eco-systematic connections and socio-economic boundary conditions. These scenarios, which will be developed within GLOWA-DANUBE and investigated with DANUBIA, will contain first of all climatic, politic, economic, demographic, and technologic alternatives to the present state and comprise changes in the use and use intensity of the land and water resources. Within the framework of GLOWA-DANUBE, local interest groups will be taken into account in defining the scenarios as well as in analyzing and evaluating the results. In the final stages, DANUBIA will be available to all parties concerned with water-resource-management (policy and administration, planning agencies, non-governmental organisations (NGOs), science and economy) as planning and management tool.

   In the first project phase, primarily climatic scenarios and alternatives to use and use intensity of the land and water resources will be developed and investigated with the DANUBIA prototype. Special emphasis will be given to studying the influence of relatively simple external factors upon the quantity and quality of the water resources in F2-catchment areas. Additionally, DANUBIA's principles will be pointed out in relatively simple and manageable examples and common evaluation procedures will be developed and collated between the separate disciplines.

GLOWA-DANUBE's long-term objective is to provide a decisive contribution to developing a globally applicable tool for the simulation and comparison of sustainable development alternatives for a wide range of environmental conditions.

To develop and validate DANUBIA, the Upper Danube through to the discharge gauge Passau-Achleiten (incl. the Inn river) is used. This area is extremely suitable as a F2-catchment area due to the following characteristics:

1. an excellent natural science and socio-economic data base,
2. due to the Alps, strong gradients exist in all natural (e.g. climate, hydrology, vegetation) and socio-economic (e.g. use, settlements, economy) factors in the catchment area,
3. strong usage of the natural resources connected with water through various economic activities within the catchment area,
4. strong present and foreseeable conflicts in water use (with respect to quality and quantity), export of water to other catchments as well as a strong import/export of virtual water (used in the production of the goods),
5. vast scientific expertise in the federal states bordering the Upper Danube, Bavaria and Baden-Württemberg, for research of the raised tasks.

Embedding in National Research

The Upper Danube serves as an exemplary case study for important questions concerning mountain-foreland-relationships and their role in Global Change of the Water Cycle. It is viewed by the project partners in accordance with the GLOWA call for proposals as a central part in the selected North-South-transsect along manifold climatic, hydrologic and cultural gradients. Thus, based on the solid and vast data base of the Middle European catchment areas, it provides expert knowledge and methods concerning changes in the water cycle in mountain regions and their forelands, to all GLOWA-projects. It is conceivable, that this will be of great use to the other groups working in North and South Europe, North Africa, West Africa and perhaps Central Africa. Therefore, a close cooperation has been arranged with these groups from the beginning of the project onward. Corresponding agreements have already been set up with the project partners from the group working on the Elbe catchment. A direct coordination of the research work especially with respect to the question of the water transfer from Danube to Elbe catchment and the exchange of methods has been agreed upon.

GLOWA-DANUBE differs from KLIWA (Climate and Water Balance), an initiative of the Water Resource Agencies of the states Baden-Württemberg and Bavaria and the German Weather Service. In contrast to KLIWA, which concentrates exclusively on past and possible future climate changes and their impact upon the water balance, GLOWA-DANUBE aims at an integrated handling of the scientific and socio-economic aspects of sustainable management of the water resources. The working group KLIWA and these project partners have agreed to make the results from KLIWA and GLOWA-DANUBE mutually available and usable. To do this, preliminary talks have been carried out.

GLOWA-DANUBE will use the geometry of the Hydrological Atlas of Germany for standardization.

The Upper Danube Catchment Area

The Danube is the second largest river in Europe. 15 countries share its catchment area of 817,000 km². GLOWA-DANUBE is limited to the analysis of the Upper Danube to the discharge gauge Achleiten below Passau. Together with the catchment area of the Inn, it has an area of 77,000 km². The altitudes range from 286 to 3,600 m a.s.l. in the catchment area. This causes strong spatial, topographical and meteorological gradients (precipitation: 650 to >2000 mm/a, evaporation: 450-550 mm/a, discharge: 150-1600 mm/a, average annual temperature: -4.8 – +9 °C) as well as a strong differentiation in land cover and land-use. The natural vegetation zones in the catchment area range from alpine grasslands, green alder and dwarf pine stands, mountain pine, mixed stands, to the dominating beech stands and oak-hornbeam woodlands. Alluvial flood plain forests are found in areas near rivers. The present land-use is determined anthropogenically, whereby agricultural use of different intensity (grassland, farmland) and forestry dominate. The high amount of precipitation in parts of the catchment area is disadvantageous for agricultural use. The catchment area is shown in Fig.1.

The Upper Danube is a region with a definite water surplus. The hydrology of the Upper Danube is characterized by strong impacts due to relief. All discharge regimens from straight nival through to pluvial occur. Floods also occur frequently. Generally they are triggered regionally by convective summer rains in the alpine foreland and in the Alps. However, characteristic large-scale weather patterns (e.g. Vb) also trigger floods, which have an impact upon the whole Upper Danube region and its tributaries (e.g. the Pentecost Flood of 1999). The water resource management in the Upper Danube is complex and characterized by the different bordering countries: 73% of the Upper Danube is managed by the German states Bavaria and Baden-Württemberg, 24% by Austria and the rest by Switzerland, Italy and the Czech Republic. The Inn, as the most important "tributary", contributes up to 52% of the average discharge (MQ) of 1420 m³/s to the discharge measured at gauge Achleiten downstream of Passau.

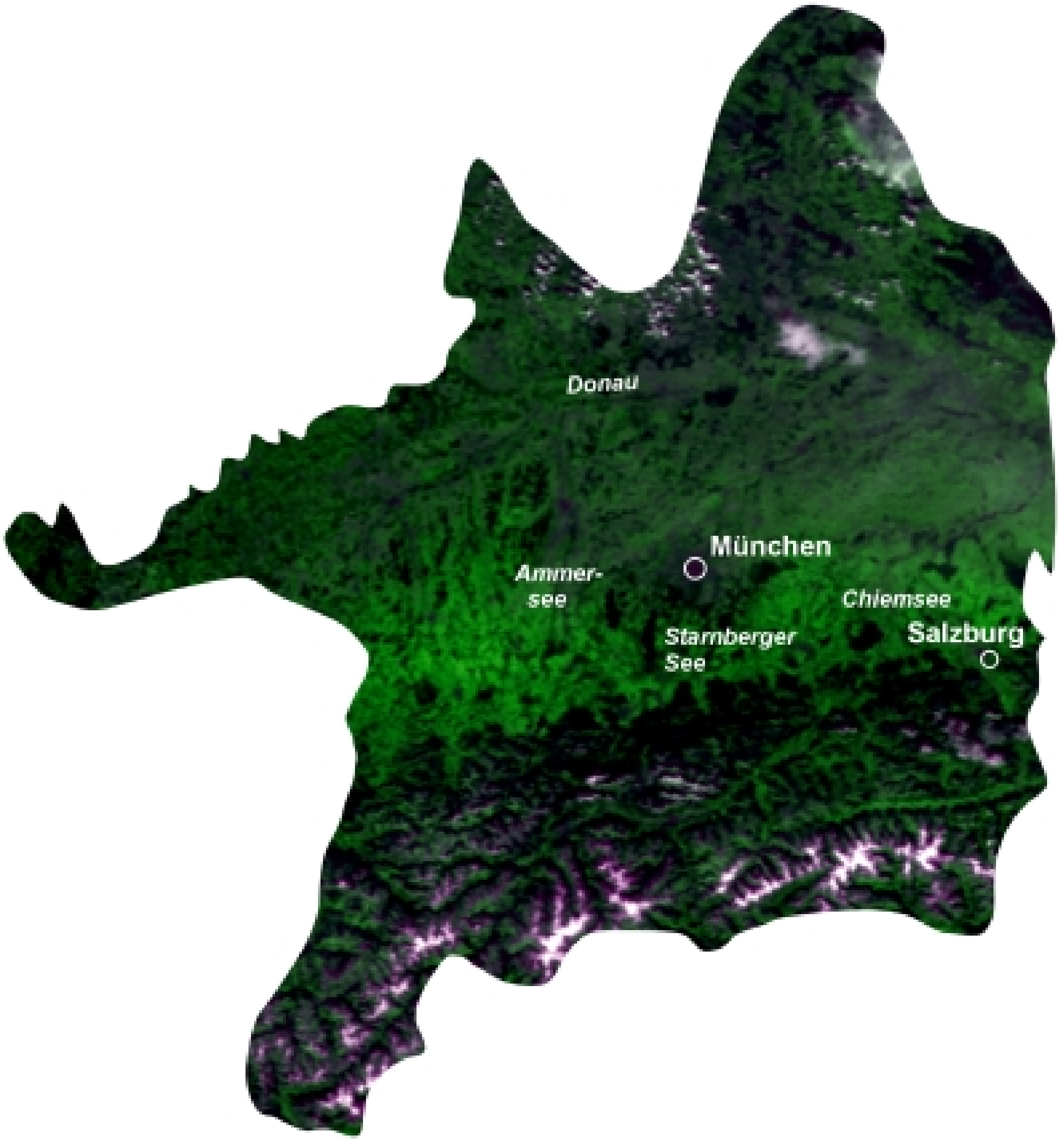


Fig.1: Catchment Area of the Upper Danube (NOAA/AVHRR image from 3.7.1999, 1 km resolution)

The catchment area of the Upper Danube is densely populated with ca. 8 Mio. people. A large part of the water for the water supply of the larger cities and the industry originates in the pre-alpine region and the Alps. The most important industrial agglomeration areas are Munich, Augsburg and Ingolstadt and the chemical triangle Burghausen.

For flood protection and for water-resource-management purposes, the discharge of all important tributaries of the Upper Danube has been regulated through reservoirs. Numerous power plant at rivers and reservoirs are used to produce energy. To a large extent, their management is determined by the dynamics of the snow and ice storage in the Alps. Parts of the Upper Danube are navigable and are part of an important waterway that connects the Black Sea with the North Sea. This waterway is already used to export water out of the catchment area of the Upper Danube into the Rhine-Main region and beyond. It is to be expected, that the anthropogenically influenced export of the water resources out of the catchment area of the Danube during the course of a more intensive and more coordinated water use in Europe will play an increasing role. Withal, the ecological and socio-economic effects as well as the environmental capacity of the water resources are still largely unexplored.

Water Use Conflicts in the Catchment Area

At the present, the strongest water use conflicts in the catchment area of the Upper Danube exist between agricultural use and as drinking water, due to fertilizer and pesticide drainage into the groundwater. In order to mediate this conflict, the states of Baden-Württemberg and Bavaria have adopted different strategies (water surcharge (Wasserpfennig), SchALVO, small-scale water protection concept vs. large-scale groundwater protection, compensation payments). It is to be expected, that the water supply structure and drinking water exploitation in the catchment areas will be centralized in the course of the catchment related water management of the European Water Resources. The basis for such a strategy of common usage and balancing of interest beyond the catchment boundaries has not yet been reached among the participants involved. Balancing the interests is aggravated by the diversity of the participants involved and by existing structural dependencies which are due to the fact that changes in the upstream catchment areas have an impact upon the downstream catchment areas and must be taken into account in the management of the catchment.

At the present, strong conflicts of use also exist in the Upper Danube area between agricultural use and forestry as well as between tourism and environmental protection. Southern Bavaria is the center of tourism in Germany. Tourism is a decisive factor in the Bavarian economy and produces jobs. Agriculture, forestry, tourism and environmental protection compete against each other in shaping the landscape and the industrial structure of the alpine forelands and in the Alps. In this context, especially the artificial snow production and the ski runs, the avalanche protection forests and the water quality of the lakes and rivers must be mentioned.

Especially the alpine area of the Upper Danube is being increasingly limited in its development possibilities due to spontaneous mud flows and avalanches caused by the relief. A combination of the factors water, land-use changes as well as the settlement dynamics in the valleys of the Alps plays an essential role in both cases. A steady decrease in the groundwater levels in the alpine foreland has also been observed for several years. The causes for this and the significance with respect to a sustainable water resources management are still largely unclear.

It is to be expected, that climate changes will lead to strong land-use changes. However, these changes are also affected by other factors, that are not related to climate change. Among these are:

- the creation of cultivated plants with a higher resistance to cold, precipitation, and parasites and their changed yield structure,
- changes in the vegetation growth and the water use efficiency due to increased CO_2 concentrations, especially at higher altitudes,
- the conspicuous deterioration of the prerequisites for agricultural production in the Mediterranean area due to decreased precipitation. As a result, the Bavarian alpine foreland will be more strongly used to maintain the European food production. The ecological, economical, and societal effects have not yet been assessed. There are also no strategies available to handle such situations.

The heterogeneity of the natural and anthropogenic conditions, the diversity at different scales, the great importance of the demonstrated present and future water use conflicts, as well as the mutual dependency between the upstream and downstream areas and the resulting conflicts in the Upper Danube area are typical for F2-type alpine catchments in developed, humid regions. This heterogeneity is caused by the altitude gradients and the resulting matter transport (water, fertilizers, pesticides, etc.) as well as the intensive and manifold anthropogenic uses. The fluxes of water and matter in the Upper Danube catchment are affected by anthropogenic impacts to a degree, which is hardly exceeded by any other developed mountainous catchment. The diversity of uses as well as the abundance of the anthropogenic regulation measures lead to a dynamic and only apparent equilibrium. However, this equilibrium is not sustainable, due to strategies to transfer and avoid conflicts. It is not regarded as a problem, that the pronounced, spatial dependencies which are typical for mountainous catchments and their forelands, result in a sensitive reaction of the water balance of the Upper Danube to changes in climate, land-use, and management at all temporal and spatial scales. The question arises though as to whether the momentary usual practice of a non-sustainable water and matter budget is economically feasible in the long run.

Thus, three factors define the Upper Danube catchment as a prototype of a F2-catchment in accordance with the call for proposals:

- The diversity of the natural conditions and the anthropogenic impacts.
- The excellent availability of meteorological, hydrological, socio-economical data as well as relief, soil, and land-use data of high quality and temporal-spatial resolution.
- The extensive expertise of the participating scientists, who have come together to create this project, concerning the regional conditions in the catchment.

Thus, with respect to its Global Change relevance, the Upper Danube catchment is characterized less by a lack of water as by a lack of substantiated definitions of the various future functions, which catchments of this type must meet as important and sustainable global water supply areas, particularly with regards to sustainable management of the natural resources, even beyond the borders of the catchment area.

Basic Approach and Methods

Up to now, there is no commonly recognized method available to integratively describe the interactions between the partially very different natural and anthropogenically determined processes over the wide range of considered climates and catchments, and to simulate scenarios about the future development. The main obstacle regarding the integration is the large difference in the way that the various disciplines formalize and describe their understanding of the respective processes. This results in differences in terms and concepts, differences in comprehension of the involved scales and dominant processes, as well as different methodical approaches. Due to these reasons, numerous investigations exist, in which the respective disciplines developed their separate contributions for solving this task, which however can only be solved through an integrative approach. Thus the combination of these disciplinary approaches often led to failure.

Basic Approach

Therefore, the central approach of the project is the *common* development and use of the Decision-Support-System DANUBIA. At the end of the first project phase, it shall quantitatively describe the interactions of the different disciplines concerned with water fluxes for the complex F2-Type catchment and it shall also cover simple scenarios about the future developments and their influence upon water quantity and quality in the Upper Danube catchment. Simple scenarios are characterized by a manageable number of future changes that they cover. In the simplest case, this is one factor and is either climate or land-use change. In contrast, complex scenarios have several changing factors that interact, and in the most complex case, these factors change during their development as a result of mutual interactions. In the second phase, procedures shall be developed and applied for the common evaluation of the sustainability of the various investigated, now complex scenarios of the future global and regional changes. These procedures shall include local stakeholders. This will lead to a refinement and improvement of DANUBIA. In the final phase of the project, DANUBIA shall be prepared for practical applications.

DANUBIA describes the involved processes with a spatial differentiation. Thus it allows the explicit determination of lateral redistributions based on fluxes of water, energy, and matter as well as migration and capital within the involved catchments and beyond. In the fully developed stage, DANUBIA will cover the following lead-substances, whose fluxes will be integratively modeled: water, carbon, nitrogen, phosphorus and capital. The main themes covered by DANUBIA are water use, drinking water quality, quantity, and availability, water export, possibilities and limits of the economical and political controls, prices, and political acceptance.

Methods

The methodology used to develop DANUBIA is characterized by applying integrative numerical model development (Unified Modeling Language, network-based models) methods and integrative monitoring (e.g. remote sensing). In the area of integrative numerical modeling, the necessity of improving the optimization of the industrial production cycle across all areas of the production processes has led to two methods in informatics in the last years. These shall serve as the basis for developing a new approach for integration of the disciplines in GLOWA-DANUBE:

1. formal languages, which will enable the involved disciplines to model sub-models of very complex systems as well as their interactions in a common way. These Meta-Modeling languages describe the essence of the modeling in a way that is independent of the respective discipline. It is thus very well suited to formulate the interaction and communication between the various processes and to check for completeness and functionality. The Unified Modeling Language (UML) is such a language and has developed within a few years to the industry standard. UML shall be used in the project as the common Meta-Modeling language for all groups.
2. The networked communication of distributed objects (i.e. independent, self-contained parts of a model compound). Hereby, the possibilities of the increased degree of networking are used, in order to enable the various elements of the whole model or model compound (called objects in the rest of the text) to be able to run in a network on different computers in different places (namely the places with the most expertise). The communication consists of an exchange of data and methods and in the synchronization of the various model elements. Furthermore, the possibility to subdivide complex and voluminous applications onto a large number of different networked computers theoretically enables an almost inexhaustible computer capacity. This is not urgent for this project. Rather, the standardized communication infrastructure, which is needed for the distribution of the objects in the network, shall be used in order to integrate the different model elements of various groups, which were developed in different places and with different programming languages. A prerequisite for this is that only selected, standardized communication procedures will be used by all groups. The industry standard in the area of communication between distributed networked objects is the Common Object Request Broker Architecture (CORBA). CORBA is used in this project in order to allow the communication of the networked objects from the various groups.

On this basis, with DANUBIA, a system will be developed that consists of distributed networked objects and which can communicate through CORBA in the net. The mutual networking of the objects is described with the Meta-Modeling language, UML, independent of the discipline. Each discipline contributes its part of the complex model compound as an object. An object is an encapsulated unit, which completes a distinct function in the Decision-Support-System and carries out the data exchange and the synchronization through defined interfaces. Hereby, the object can be implemented in any desired language.

This selected concept of a network-based, distributed model compound for integrative modeling is new. However it is foreseeable, that along with the expansion of network technology and the internet, this concept will prevail and provide the basis for interdisciplinary work in the future. In this sense, the project plans to provide basic research in the development of interdisciplinary integration techniques.

Modeling Concept

Beyond the use of industry standards, the following characteristics and concepts make certain that the set-up of DANUBIA is feasible:

- As shown schematically in Fig.2, DANUBIA is *raster based* at its core. This simplifies the interdisciplinary description of the interactions between the considered processes. The spatially distributed, raster based modeling of the core processes (run-off generation, evaporation, plant growth, economics, agents) are expanded at first by one-dimensional modeling of the processes in flumes and water bodies with regards to quantity, matter turnover, and management.

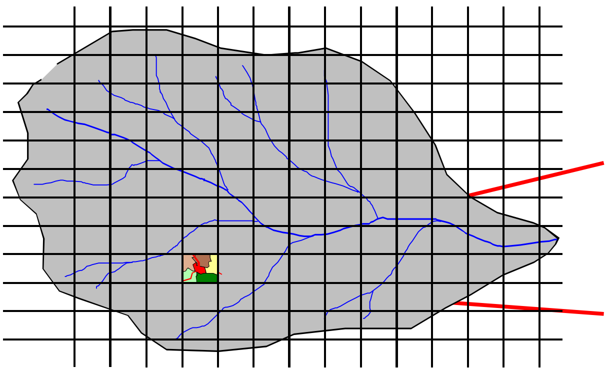


Fig.2: Schematic raster based modeling in DANUBIA on the pixel basis. The red lines connect to Fig.3

- DANUBIA uses the *concept of "Proxels (process pixels)"*. Proxels are the basic elements of DANUBIA and consist of a pixel in the form of a cube, in which processes occur (Tenhunen et.al., 1999). This cube, which has different dimensions depending on the viewing scale, connects to its environment (other proxels) through fluxes. An object of DANUBIA can thus be e.g. a surface proxel, that describes the water flow on the surface. Encapsulation allows the management of the involved processes, in this case evaporation, surface run-off, lateral run-off in the unsaturated zone, and percolation into groundwater. It also enables the management of the necessary parameters within the object and to carry out data imports and exports via defined and standardized interfaces. For further development and improvement, all characteristics of a proxel can be handed down to the later versions of the programs, i.e. are available for reuse, scaling, and refinement. In the same way, this is realized for natural science processes as objects. Socio-economic processes (behavior, market situation, perception, etc.) are described on the basis of proxels. This concept is to be used for the integrative tasks in GLOWA-DANUBE and to be expanded at the appropriate places.

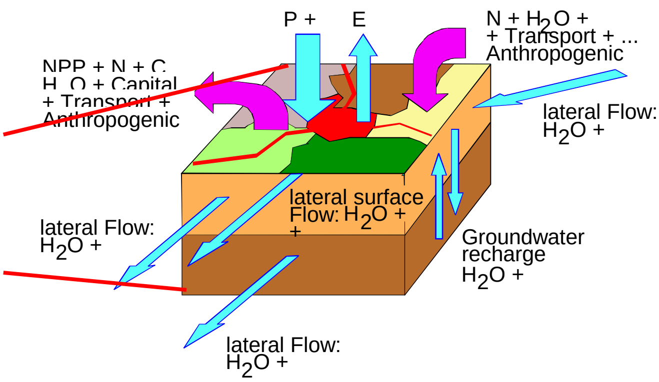


Fig.3: Simplified schematics of a proxel as a basic element in DANUBIA using a land surface proxel as an example.

- In DANUBIA, a proxel-area of 1 km² is used for the mesoscale modeling of land surface processes as well as for the key socio-economic processes in the entire catchment area of the Upper Danube (A ~

80.000 km²) and 1/10 to 1 ha for the planned detail studies of characteristic sub-catchment areas of the Upper Danube (A ~ 1000 km²).

- In socio-economics, DANUBIA uses the concept of *agent models*. The core idea of an agent model is that *every single* agent involved is modeled in a domain of individuals. Thus, this procedure differs fundamentally from all summative modeling approaches, in which the input-output-functions of a whole system are described. Agent models can be subdivided into shallow and deep models, according to the theoretical content. *Shallow models* specify the input and output connections of the behavior of single agents with little or no theoretical assumptions. This can occur mathematically or also through neuronal networks. *Deep models* generate the behavior out of a theory about the agents and enable semantically meaningful statements about the motives of the agent. Methods used here are e.g. symbolic modeling, in which decision making is described as a sequence of rules.
  Agent models can be used successfully, if a meaningful standardization of the agents can be carried out. Modeling of the agents enables not only a detailed extrapolation of behavior (which is important in the case of DANUBIA, with respect to the agent types as well as the spatial distribution), but is also easily expanded and refined. A deep model enables mapping and interpretation of the dynamic phenomena of adaptation, learning, and interaction.
  At first, agent models will be used in the DANUBIA model compound psychology. In the second project phase, they will also be developed in water resources management/groundwater and in political science. At first, shallow models will be used. Especially in modeling political agents and water supply companies it is obvious that a deep, i.e. theoretically based modeling of the agent behavior, is a very demanding task. Besides this, in a dynamic and highly interactive domain, prognoses based on such a model will initially have a rather exemplary character. On the other hand, this project tries to develop summary models via shallow agent models through to deep models and check for soundness.

Networking Concept

In the course of setting-up, validating, and applying DANUBIA, models and methods from the following natural and socio-economic disciplines will be involved:

Hydrology (Schneider/Mauser)
Meteorology (Wirth/Egger)
Water resources management / Groundwater (Braun/Kobus)
Water resources management / Surface waters (Willems/Kleeberg)
Plant ecology (Tenhunen/Kastner-Maresch)
Glaciology (Kuhn)
Remote Sensing (Bendix und Mauser)
Environmental Psychology (Ernst)
Environmental Economics (Sprenger/Wackerbauer)
Tourism Research (Schmude)
Informatics (Hennicker/Wirsing).

The core groups from the first project phase of the projects are in bold print.

Each participating core group will develop an object based on their available disciplinary model approach and knowledge and partially with the help of the bridge groups. The objects communicate through a standardized mechanism, which will ensure that for every time step in the model calculations, the spatial data (e.g. temperature, radiation, biomass, income, etc.) and parameters (e.g. water-import, suggested subsidy of corn, etc.) required by a partner-object will be provided. This mechanism is thus comparable with a market place, in which data are offered and exchanged. An object can simultaneously be the supplier and receiver of data. This ”Market place concept” was developed and refined through intensive discussions within the project groups and is shown in Fig.4.

The ”Market place” in this figure is the sum of all boxes outlined in black. They show the essential parameters, that can be exchanged between the objects, generally as grid data. DANUBIA’s structure provides for the synchronization of the data exchange. This kind of interaction structuring between the groups enables the respective points to be clearly identified, in which scenarios regarding the future development are entered into the system. These scenarios are external factors of the catchment, such as climate change (meteorology), EU-political boundary conditions (politics), or in the area of psychology (e.g. agent decision, life-style changes), or economics (e.g. changes in prices, supply, technologies, industrial structure, etc.). In this sense, economics is of prime concern in the selected structure. For instance regarding the introduction of a new cultivated plant and its impact upon the water balance, the optimization of the cost structure of the agricultural production is of prime concern and requires an answer to the question of the production costs and impacts upon water quality and environmental influences. At first, the property-structure of the plant is determined by the economical viewpoints, whereby the ecological consequences of the introduction can only be foreseen with great difficulties. The groups plant ecology, hydrology/remote sensing, groundwater and water bodies react to this change by searching for an optimal region to cultivate these plants, by setting-up fertilizer plans, by letting these plants grow according to meteorological data (today’s and future data), by quantifying their influence upon the water cycle and sending feedback to the disciplines of psychology and economy about the resulting data regarding the fluxes of water and the water quality. In a further step, psychology has the possibility to react unsatisfied, which induces politics to check the regulations.

Since the various data have to be available in different time steps, the mutual synchronization of the objects is a central task. This can be carried out with UML relatively easily and independent of the discipline.

These methodical approaches are breaking new ground. The possibility to reuse the developed code (through object-oriented programming), the easy serviceability of the interfaces (through standardization) and the inherent explicit documentation through the use of the Meta-Modeling Language in this approach, create new integrative structures between the participating scientists. They also easily allow the introduction of refined and improved algorithms into the structure, as implied in the ellipses in the core groups. The core groups start with a simple implementation of its functionality (phase 1) and continue by gradual improvements of the methods (phase 2 and 3) (for details see the individual project descriptions). Based on this, a prototype of DANUBIA shall be developed, that will already contain all basic characteristics of the final system. Building upon this, validation, refinement, and application of the created objects and interfaces will follow with a wide selection of Global Change tasks and scenarios in the Upper Danube catchment. Basic approaches for their formulation are given in the description of the catchment areas. After the initial phase, regional stakeholders and interest groups will be included in the validation and improvement as well as in the development and handling of scenarios, in order to assure the relevance and applicability of DANUBIA.

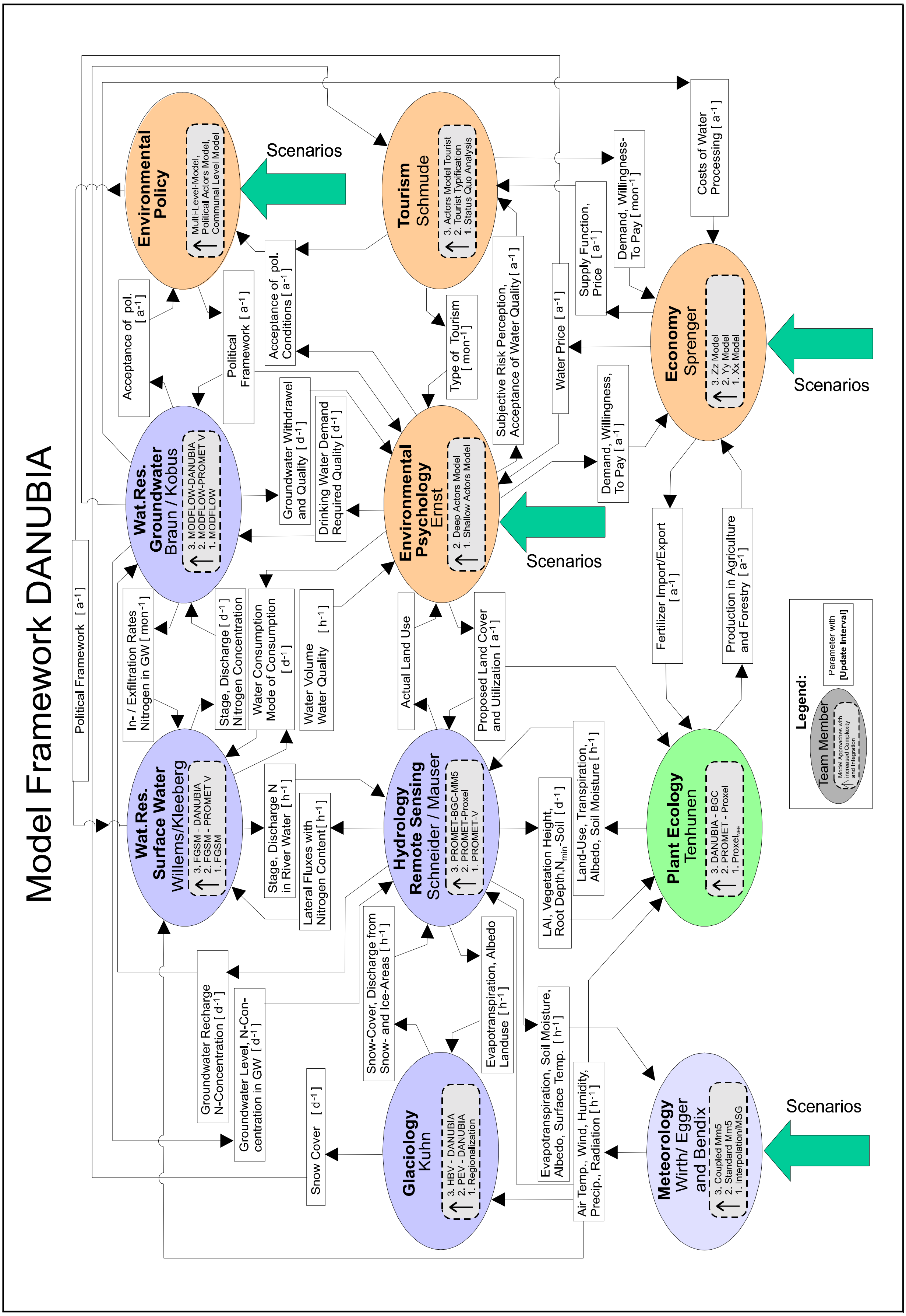


Fig.4: Networking of the participating groups in the project as shown with the help of the data exchange between the groups and gates for the development of scenarios.

Multi-disciplinary terms are used as follows in GLOWA-DANUBE:

- *Microscale* is the scale, with which a scale element (proxel) describes a homogeneous surface unit. The catchment may reach up to 1000 km², proxel size up to 100x100 m.
- *Mesoscale* is the scale, in which a proxel is described on a sub-scale basis, whereby the meteorological forces do not leave the assigned climate region and the cultural and economic relationships do not leave the assigned cultural or resp. economic unit. Catchment area size is up to 100.000 km², proxel size up to 1000x1000 m.

Time Frame

The development, validation, and application of DANUBIA shall occur in three phases, which are concomitant with the project phases in the GLOWA call for proposals:

1. Phase (Year 1-3):

This phase is covered by the ongoing project activities.

- **Development of the DANUBIA prototype**
  This phase is characterized by development, testing, merging and improving the objects that contain the disciplinary process description. The objects will be developed on the basis of the existing knowledge and models in the participating groups under utilization of the common Meta-Modeling language and combined, based on defined interfaces. The further development and adaptation of the Meta-Modeling language and the structure of the integrated modeling system upon the specific formal needs of the integrative Global Change Research within the group is the central task of the informatics group.
- **Development of Procedures for Aggregation and Disaggregation of Process Descriptions and Data (Scaling)**
  In the development of DANUBIA, different scales need to be concurrently considered. Above all, this is due to the fact that processes with a pronounced spatial character (e.g. percolation or evaporation) interact with linear processes (e.g. flume flow or traffic flow) as well as with processes without any direct connection to scales (e.g. political decisions, where the impacts are disaggregrated). Depending on the selected procedure description and scale, these processes can be explicitly and mechanistically described (microscale) or they must be described on a sub-scale basis (mesoscale). The transition from microscale to mesoscale and back is, at least in the natural sciences, always complex if the described processes are not linear and the case studies being investigated are heterogeneous. This is especially valid in regions with pronounced relief, such as the Upper Danube. Generally, all of the processes under consideration are not linear and furthermore, the Upper Danube as a case study is very heterogeneous on different scales. Thus, it can be expected that when using spatially distributed models in the Upper Danube, spatially averaged input data deliver different results than a spatial averaging of the model results, which were obtained with spatially detailed parameters. In socio-economical areas, knowledge and instruments for scaling are lacking to a large extent (e.g. from the individual to the group, from makro-economic descriptions into micro-economy, from the regulation to the involved person). Yet, decisions are made at different scales (e.g. city, county, state, federal, EU).
  Our goal is to develop scale overlapping objects, which will deliver equivalent model results on both scales. So far all involved disciplines mainly lack procedures which enable to:
  - model the pronounced sub-scale heterogenities at the mesoscale (1km), such as valleys in the Alps (relief), exposition dependent vegetation distribution, aggregated canopy resistance, convective precipitation, lateral fluxes of water and matter, behavior of agent groups based on individuals, capital flow, etc. based upon the knowledge available on the microscale

- provide spatially distributed information on the mesoscale about consequences of impacts at the macroscale (e.g. global climate changes, changes in the macro-economic prevailing conditions, EU-agricultural subsidies, EU-water-framework directives) upon the Upper Danube catchment.

In addition, tools are lacking to disaggregrate the mesoscale results obtained from DANUBIA to the microscale, where sustainable planning decisions also must be made. To develop these in the first project phase, in the areas hydrology, glaciology, plant-ecology, remote sensing, tourism, environmental psychology and environmental economics, the necessary investigations at the microscale in various test-catchments will be carried out with the aim to develop upscaling or resp. downscaling procedures. In the first phase of the project, the microscale investigation will be concentrated at the test-catchments Ammer and Donauried (see Fig.11).

With remote sensing observations, the heterogeneity of the landscape which is the subject of the scale questions, can be determined at different scales. This can be done by repeatedly determining the reflection and emission characteristics of the Earth's surface at different spatial (1m – 5 km) and temporal (30 min – 35 days) scales. Remote sensing is an integrative monitoring procedure. It can synoptically determine an enormous number of land surface categories (forests, agriculture, settlements, road network, standing bodies of water, flowing water, snow, ice, etc.). Only by evaluating the data beyond the individual discipline borders, can these data be fully exploited. Although remote sensing data are available world-wide in homogeneous quality, the potential of this data source for developing procedures for process descriptions at various scales has hardly been used. Therefore, in GLOWA-DANUBE, remote sensing shall be used as a data source for as many sub-projects as possible.

In order to develop objects which are applicable at different spatial scales and to validate them at these scales, the necessary amount of microscale data with respect to micro-meteorology will be collected by high resolution remote sensing systems or through surveys (see chapter on Implementation).

- **Development and First Usage of Global Change Scenarios to Test DANUBIA**

Existing scenarios with regards to Global and Regional Climate Modeling and scenarios about the further development of the population structure and the land-use structure as well as intensity of use (fertilizers and pesticides) shall be used as a first test of DANUBIA and to demonstrate its fundamental functional capacity and applicability. This will be completed in two stages:

1. available data from the period 1970-1999 are used as a baseline scenario, in order to show that DANUBIA can correctly model the present conditions. For this, the data from meteorological and hydrological networks, land-use data from remote sensing sources, available demographic statistics and water use statistics will be used.
2. Two scenarios of changes in climatic drivers will be selected from those available in due course. Based on the changes determined in the drivers, changes in the water availability (ground and surface water) and agriculture as well as changes in forestry and tourism will be investigated in the first project phase.
3. Scenarios of changes in land-use and intensity will be developed on the basis of changes in subsidies paid for various cash crops or agriculturally used fields (e.g. corn, meadows) and usual agricultural practices. Then they will be disaggregrated onto the area of the Danube catchment according to local and economical conditions. From this, possible future land-use distributions, as alternatives to the current land-use, along with the present and possible future climate data, can be used to determine the quantity and quality of the water resources.

In further talks, the following simple scenarios were considered as suitable for handling in the first project phase:

Climate:

In the framework of the MM5-Model calculations, it is assumed that the only climatic change is due to homogeneous increases of the temperature of the atmosphere by a set amount (e.g. 3 degrees).

Everything else stays the same, especially the variances, the wind directions and strength, the atmospheric pressure, etc. This scenario should be viewed as a possible and physically realizable development.

Politics, Psychology and Economy:

In the framework of the general political conditions, it is assumed that increased subventions are paid for growing corn or raising cattle, which lead to a change in the cost calculations for these economic processes. These prevailing conditions make it necessary to assess the regional impact of such measures (i.e. where is it possible to grow corn under the given conditions). Under customary agricultural practices, changes in the water pollution load are derived from these data.

Introduction of drinking water saving technologies in households provides an additional scenario.

- **Development of scenarios and analysis of the water-use-conflicts in the Upper Danube**
  In the chapter "The Catchment Area of the Upper Danube," the essential present and foreseeable future conflict sites in water use of the Upper Danube were covered. They can be divided into internal and external conflicts and scenarios. Internal conflict scenarios will be developed for the areas of agriculture and drinking water supply, landscape conservation, tourism and the competing national and state structures, which are involved in managing the water resources in the Upper Danube catchment. The most important aspects in this context are: the nitrate content of the groundwater, the decreasing groundwater levels and the restructuring of the water supply. The development of external conflict scenarios will initiate investigations about the consequences of withdrawing water out of the Upper Danube and about the impact of climate change upon the water availability in the Upper Danube, as well as its impact upon the restructuring of industry (services, chemical industry, semi-conductor industry, air and space agencies, etc.).
- **Set-up of a Geographic Information System and a common data pool for the Upper Danube**
  A prerequisite for the development of the spatially distributed Decision-Support-System DANUBIA as well as for investigations of processes in the microscale test sites, is a commonly available data pool. As far as possible, DANUBIA should be developed on the basis of existing data or with obtainable data from operational networks. These data are available through the German Weather Service, water resources management agencies, survey, agricultural, and geological agencies, etc. of the involved states and countries as well as through the operators of earth observation satellite systems. Due to the manifold disciplines, these data are very heterogeneous (spatial data, point data, statistics, etc.). Therefore, one position should be assigned to the coordinator's team to handle the provision of the data. In addition, minor amounts of small-scale point measurements for process descriptions and validation of the models will be needed from various test sites for the investigations of scaling problems in the areas of hydrology, meteorology, improvements in precipitation modeling, plant ecology, etc. They pertain to the energy balances and soil moistures and should be set-up and coordinated by the individual project groups and maintained by the specified position (maintenance, data retrieval). Three areas are to be covered:
  - Collection, quality control and availability of the spatial data for the entire project within a Geographic Information System (GIS). It is to be expected that at first, the sub-projects will provide time series of spatial data (land-use, plant parameters, precipitation, radiation, remote sensing data, DEM, etc.) as well as spatially distributed model results (e.g. meteorological drivers, etc.) in different formats. These must then be transferred to a common data base format and made available to all groups.
  - Collection, quality control, availability, and localizing of the station data from the meteorological and hydrological agencies as well as basic data, such as diverse statistics (population, income, industry, etc.), drainage systems, gate discharge locations, etc.. These data will be obtained, checked

for quality, documented in their format and as soon as possible (within the first year) made available to the groups via internet.

- Data collection, processing and availability of the ground truth data from the test sites.

The data records will be available to all sub-projects.

2. ***Phase (Year 3-6):***

Based on the results of the first phase, in which in the basic structure and functionality of DANUBIA will be developed, the following further steps are planned:

General:

- Work in close concert with the International Commission for the Protection of the Danube (IKSD).
- Expansion of the working groups in the areas sociology, regional planning, land-use politics, and technology
- Development of more complex scenarios under active inclusion of the stakeholders and local agents.
- Coordination of the development of DANUBIA with planning agencies and industry.
- Improvement of the integrative process descriptions in DANUBIA through refined sectoral process descriptions and improved interface handling. Above all, this concerns the social sciences, whose focal point in the starting phase was in data collection to determine the actual state (politics and tourism). Here, the plans are to develop agent oriented models and integrate them in DANUBIA. These are needed for the analysis of the more complex scenarios.
- Development, improvement, and management of complex scenarios especially based on the knowledge of the economic, psychological, political, tourist, and plant-ecological groups. To improve DANUBIA, in this phase the regional interest groups will be included, perception studies will be carried out for the different scenarios guidelines, agent models will be refined and the data assimilation and monitoring procedures in the natural and social sciences will be improved (e.g. operational use of remote sensing).
- Presentation of DANUBIA to the involved interest groups and administrations and discussion of the system with the users. Definition of further system requirements.
- Expansion of the test sites to include the Naab catchment, integration of decision-support-components for GLOWA-DANUBE.

Hydrology/Remote Sensing:

- Determination of soil moisture from ERS and ENVISAT-ASAR data, as well as integration of the remotely sensed soil moisture information into the flux models for water and matter
- Modeling of the nitrogen turnover in agriculturally used areas
- Development and evaluation of hydrological scenarios
- Evaluation of high resolution remote sensing data for scaling investigations

Meteorology:

- Investigation of interaction between precipitation and relief.

Informatics:

- Research of methods and techniques to specify interacting processes and for the systematic development of program codes from process specifications.
- Refinement of the sectoral process descriptions and improved handling of interfaces.

Water-resources management/Surface water:

- Reservoir management

Water-resources management/Ground water:

- Dynamic change scenarios in the 3 sub-areas
  - Changes in the spatial-temporal groundwater resources
  - Application of the agent models ”Water supplier”
  - Application of the agent models ”Water user”

Glaciology:

- Coordination of the detailed HBV Model with the Index Model from the Institute for Meteorology and Geophysics of the University of Innsbruck, verification in glaciated and ice-free catchments
- Application of the models on all alpine tributaries of the Inn and the Salzach, and verification
- Elaboration of the specific model characteristics for crystalline and limestone
- Calculation of the reaction to various temperature and precipitation scenarios
- modeling of the impacts of power plant management (daily and seasonally)
- Adaption and verification of the models for flood events at different snow covers.

Psychology:

- Refinement of the deep model, long-term substitution of a qualitative agent model for the shallow quantitative estimation
- Inclusion of the Austrian/Swiss areas of the Upper Danube with regards to the socio-economic considerations
- agent models in water-resources management/groundwater and politics together with the respective groups
- Scenario composition

Tourism:

- Development of an object, that describes the tourist agents in DANUBIA.
- Expansion of the analysis to Austria.

3. *Phase (Year 7-8):*

In this phase, DANUBIA will be prepared for operational use. This involves that a useable model be developed for decision makers by which different scenarios in the Upper Danube catchment can be simulated in order to support the necessary decisions.

Project Structure

GLOWA-DANUBE is made up of the following 8 core groups:

Group	Scientist	Place	Short description
Hydrology/ Remote sensing	PD Dr. K. Schneider Prof. Dr. W. Mauser	LMU Munich	Development of a spatially detailed, mesoscale, hydrological object of the entire Upper Danube area as well as the development of a hydrological object applicable at different scales for evaporation, percolation, and lateral flow using remote sensing data;
Meteorology	PD Dr. Wirth Prof. Dr. E. Egger	LMU Munich	Development of a meteorological object which is coupled with the land surface object, using MM5. This will occur in two steps: a) set-up of a meteorological object through statistical spatial interpolation of measured data, b) integration of MM5 into the existing object,
Plant ecology	Prof. Dr. J. Tenhunen Dr. A. Kastner-Maresch	Univ Bayreuth	Development of a vegetation object applicable at different scales, that can treat forest and agricultural uses and is coupled with the hydrological and meteorological objects
Water-resources management/ Groundwater	Dr. J. Braun Prof. Dr. H. Kobus	Univ Stuttgart	Development of a groundwater-object for large-scale balancing of the water and matter flow in groundwater as well as objects to determine the water supply and water use structures as a basis for the psychological and economical agent models
Environmental-psychology	PD Dr. A. Ernst	Univ Freiburg	Development of an agent object ”Water-user” to describe households and agricultural and industrial operations in the Upper Danube area regarding water use, water related risk perception and acceptance.
Environmental-economy	Prof. Sprenger	Ifo-Institut Munich	Development of an agent object, that is able to spatially render the economical decisions of different population groups, investigations of import and export of water/virtual water
Water-resources management/ Surface water	Dr. Willems Prof. H.-B. Kleeberg	IFAW, Munich	Development and validation of a river network object. It will be made up of the components run-off, water quality, matter turnover, and reservoir management
Informatics	PD Dr. R. Hennicker Prof. Dr. M. Wirsing	LMU Munich	Expansion of the Meta-Modeling Language UML to formalize and integrate the model objects in DANUBIA, Development of a web-based, distributed DANUBIA-system; modeling and implementation of the interfaces; support of the groups in generation of the adapters

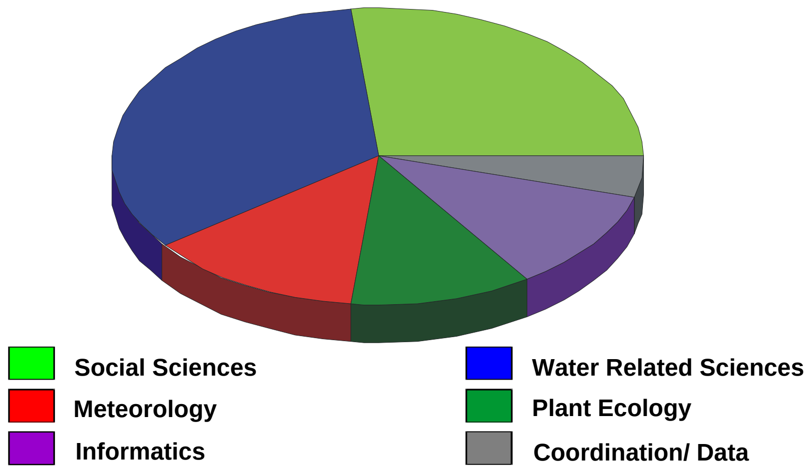
Tab.1: The young scientist groups in GLOWA-DANUBE

These groups will provide the sustaining support for DANUBIA and will be professionally and sectorally supplemented in the first project phase through the following groups:

Theme	Scientist	Place	Short description
Glaciology	Prof. M. Kuhn	Univ Innsbruck, Bay. Academy of Sciences	Development of a snow and ice object, that can model the accumulation and ablation of snow and ice based on energy balances
Precipitation	Prof. Dr. J. Bendix	Univ Marburg	Development of and improvement of a precipitation object based on remote sensing measurements (METEOSAT – MSG)
Tourism	Prof. Dr. J. Schmude	Univ Regensburg	Reduction into types of tourists according to tourism segments as a contribution for the development of the agent object in the area of tourism, behavior records of various tourist types, case studies
Human Capacity Building	Prof. Dr. H. Kobus Dr. J. Braun	Univ Stuttgart	Education and advanced training of foreign students in the forum GLOWA through organized expansion of the studies and use of the WAREM infrastructure

Tab.2: List of the bridge groups involved in GLOWA

In addition, a project of this dimension requires an administration infrastructure. This will be centrally organized by the Coordinator. The following task areas are part of administration: 1. Funding management (Project funds and central administration of the investments and travel allowances), 2. Organization of internal workshops, colloquia, and status seminars, 3. Contact partner and outside representative of the project, 4. Central provider of data that are of interest to various project groups, 5. Central data management as well as set-up and maintenance of the Geographical Information System.



Social Sciences	Groups: 6, 7,11,12 Scientists: >	6	27 %
Water Related Sciences	Groups: 1,4,5,9 Scientists: >	7,5	33 %
Meteorology	Groups: 2,10 Scientists: >	3	14 %
Plant Ecology	Group: 3 Scientists: >	2,5	11 %
Informatics	Group: 8 Scientists: >	2,5	11 %
Human Capacity Building	Group: 13 Scientists: >	0	0 %
Coordination/ Data		1	4,4 %

Fig.5: Pie diagram of the different disciplines in GLOWA-DANUBE (positions):

1 = Hydrology/ Remote Sensing (Schneider – Mauser, LMU Munich)2 = Meteorology (Wirth – Egger, LMU Munich)
3 = Plant Ecology (Tenhunen - Kastner-Maresch, Univ Bayreuth)
4 = Water resources management – Groundwater (Braun – Kobus, Univ Stuttgart)
5 = Water resources management - Surface water (Willems – Kleeberg, IFAW Munich)
6 = Environmental Psychology (Ernst, Univ Freiburg)
7 = Environmental Economy (Sprenger – Wackerbauer, ifo-Institute, Munich)
8 = Informatics (Hennicker – Wirsing, LMU Munich)
9 = Glaciology (Kuhn, Univ Innsbruck)
10 = Precipitation (Bendix, LMU Munich)
11 = Tourism (Schmude, Univ Regensburg)
13 = Human Capacity Building (Forum GLOWA, Kobus, Univ Stuttgart)

Fig.5 displays the different disciplines in the project and the number of positions allotted to each. It is clearly shown that a balanced ratio of positions between the disciplines is the aim.

Network and Integration

Intensive networking of the groups involved in GLOWA-DANUBE is the key for the success of the project. This was already shown in Fig 4 with regards to data exchange and methods. For the successful set-up of the system and the professional representation of each part in the entire concept a solid basis for communication between the groups is crucial. This ensures that a common language will be used between the various groups during the course of the project. This is a prerequisite for a common formal description of the involved processes in DANUBIA.

Especially the directly related disciplines need to be well networked in the project. Flexible working groups will be established, that will be annually reconstituted. The following working groups are intended at the beginning of GLOWA-DANUBE:

- working group **socio-economical tasks**

  This working group will assume the task of processing and presenting the commonalities, the coupling, and the interfaces within the methodical approaches of the involved social sciences. Its goal is to develop the basis for commonly formulated agent objects (e.g. water users, water suppliers, political agents) in accordance with the networked modeling and to investigate this with regard to analysis of alternative eco-political scenarios.

- working group **meteorology and land surface processes**
  This working group will assume the task of investigating the commonalities, the coupling, and the interfaces with regards to the assimilation of measured data in meteorological models as well as the realistic interpolation of meteorological data. In addition, the coupling and interfaces in meteorological modeling and land surface modeling will be investigated.
- working group **scaling**
  This working group will assume the task of coordinating the procedures in the investigations in the test-catchments and to identify common scales for the development of the models as well as developing and testing commonalities in the development of methods applicable at different spatial scales.
- working group **informatics and modeling**
  This working group will assume the task of investigating the commonalities, the coupling, and the interfaces within the different groups with regard to the conversion of the process understanding into model approaches and to define and test common solutions for the scaling problems.

Tab.3 shows the participation of the project partners in the working groups. Their participation can be either full or limited to specific themes or only temporary (in parenthesis in Tab.3).

Implementation

The development of integration techniques is an essential part of the GLOWA-DANUBE project. Existing procedures are to be further developed so that the various processes in the natural and social sciences, which are involved in describing the whole system, can be described and formulized in a common manner, thus interdisciplinarily. Parallel to this, it is necessary to develop improved models of the sub-processes for mesoscale catchments with strong relief. Hereby, the methodology used is decisive, along with the already described concept.

Based upon this, the work can be subdivided into three levels:

1. **The sectoral level**, here each working group works on their research task. The respective procedures can be taken from the individual project descriptions;
2. **The network level**, in which the working groups meet with other groups that have similar tasks and/or close connections, in order to work on common interest and to develop and test common scenarios (e.g. psychology – politics, hydrology – plant ecology),
3. **The integrative level**, in which the objects, developed by the various working groups and placed in the network, are combined to a coupled model and validated, and in which interdisciplinary scenarios are developed and tested.

Procedure at the network level

This level is characterized by a small number of working groups that meet for a limited period of time in order to find solutions for common problems. The annual status-workshop serves as a discussion forum for these working groups. The involved groups have agreed to form the following working groups (for the tasks of the working groups see the chapter on ”Network and Integration”):

- Working group **socio-economical tasks**
- Working group **meteorology - land surface processes**
- Working group **scaling**
- Working group **informatics and modeling**

This results in the following network-matrix (X = full participation, (X) = occasional):

Group	1	2	3	4	5	6	7	8	9	10	11	13
Social	X			X	X	X	X	(X)			X	
Met	X	X	X					(X)	X	X		
Scaling	X		(X)	(X)	(X)	X	(X)	(X)	X	X	X	
Inform.	X	X		X	X	X	X	X	X	X		

1 = Hydrology / Remote sensing (Schneider – Mauser, LMU Munich)
2 = Meteorology (Wirth – Egger, LMU Munich)
3 = Plant ecology (Tenhunen - Kastner-Maresch, Univ Bayreuth)
4 = Water resources management - Groundwater (Braun – Kobus, Univ Stuttgart)
5 = Water resources management - Surface water (Willems - Kleeberg, IFAW Munich)
6 = Environmental psychology (Ernst, Univ Freiburg)
7 = Environmental economy (Sprenger - Wackerbauer, ifo-Institut Munich)
8 = Informatics (Hennicker – Wirsing, LMU Munich)
9 = Glaciology (Kuhn, Innsbruck)
10 = Precipation (Bendix, Univ Marburg)
11 = Tourism (Schmude, Univ Regensburg)
13 = Human Capacity Building (Forum GLOWA, Kobus, Univ Stuttgart)

Tab.3: Network-Matrix of the GLOWA-DANUBE working groups,

The working groups will be set-up with travel funds for regular meetings. These funds will be taken out of the central administrative travel funds, whereby the costs are accounted for in the separate sub-project descriptions. Their progress will be discussed in the annual status-workshop. During the status-workshops, recommendations for the continued or reconstitution of the working groups will be introduced. The steering committee will decide about the recommendations.

However, this does not mean that bilateral and multilateral meetings are unnecessary. These meetings will be set-up by the sub-projects as necessary.

Procedure at the integrative level

To achieve the integrative aims, the involved groups have additionally agreed to introducing week-long integration-workshops and comply to the following procedure:

- Directly after the start of the project, the first week-long integration-workshop (planned for the end of 2000) for the development of the model-objects will take place. It will serve to introduce the Meta-Modeling Language, UML, and for the data exchange-mechanisms of CORBA, as well as to discuss possible object structures. During this workshop, for each group binding agreements will be negotiated about the following tasks of each group and characteristics of the respective object to be created:
  - Responsibilities in developing the objects;
  - Definition of binding deadlines for further working steps;
  - Introduction into interfaces and object structure with the help of case studies;
  - Definition of the input and output parameters and target values;
  - Definition of the applied time steps in calculating the target values;
  - Determination of the synchronous/asynchronous use of the output parameter and target values;
  - Analysis of data requirements and availability;

- Based on the results of the workshop, the working group in informatics will develop a first draft of the expanded Meta-Modeling Language based on UML.

- On the basis of the first workshop, thematic sub-groups will form to realize the prototypes of distributed, simple, network-based models based on the existing available objects and to document their experience. Due to the close contextual connections, e.g. the combinations hydrology/plant ecology and environmental psychology/environmental economics as groups are suggested.

- The second integration-workshop (1 week, planned in September 2001) will serve as a discussion round and for the further contextual development of the Meta-modeling Language and the simple case studies developed by the sub-groups. Special emphasis is placed on testing the capacity of the first version of the Meta-modeling Language for the common structuring of DANUBIA. The discussion will lead to an improved and expanded definition of the modeling language as well as to the characteristics of the separate objects.

- Based on the results of the second integration workshop, a generalized interface for the model structure will be developed in the following year. This will allow all groups to incorporate and test their objects in DANUBIA. It is very important in this early stage, that the external behavior of the objects is as close as possible to the final object. This can be ensured for instance by using meteorological input fields which are interpolated from measurements or by utilizing agent objects which are fed from data bases.

- The third integration workshop (1 week, planned in September 2002) will serve as the first common test of the functionality of the distributed model and for discussing the results obtained. Emphasis is placed on making the interactions between the objects transparent and discussing them. Based on this first executable minimal version of DANUBIA, an agreement will be reached at this workshop about carrying out the remaining model calculations for validation of the approach.

Furthermore, in the framework of the Forum GLOWA (Human Capacity Building), regular interdisciplinary training and education will take place. These training sessions will be open to the involved GLOWA-DANUBE scientists as well as to international students. Thus, they will contribute to familiarizing them with specific tasks in GLOWA-DANUBE (e.g. as diploma theses) and to promote the know-how-transfer into developing and under-developed countries. Therefore, the following working plan for the integrative aspects of the project is given:

Project year	**1**		**2**		**3**	
Project month	**1-6**	**12**	**18**	**24**	**30**	**36**
1. Workshop (IDL, CORBA, Object characteristics)	X					
Drafting of the modeling language	Xx	xxxx	xx			
Building thematic sub-groups, development of prototypes	Xx	xxxx	xx			
2. Workshop (Test of the Meta-Modeling Language and object integration)			x			
Further development of and improvement of the objects, tests			xx	xxxx	Xx	
3. Workshop (Test of the distributed models)					X	
Model calculations and validation					Xx	xxxx

Tab.4: Working plan for the integrative aspects

Selection of the test areas for working on scaling problems

The developed objects must be able to describe the sub-processes on different spatial scales. This means that the objects should deliver equivalent results for catchments of different sizes and processes with different temporal and spatial resolutions. A prerequisite for this is to work at the micro- and at the mesoscale. The involved groups have agreed upon the following procedures:

- Investigations in representative test catchments with areas of ca. 1000 km². Development catchments, used mainly in the first phase, and validation catchments, used mainly in the second phase are differentiated. The groups agreed upon the following development catchments:
  - The city of **Ulm** and the **Donauried**
    Here, the groups Braun/Kobus (water resources management - groundwater), Ernst (environmental psychology), Sprenger (environmental economics), Schneider/Mauser (hydrology/remote sensing), Bendix (precipitation) will carry out common detailed investigations of the groundwater dynamics, groundwater quality, nitrogen dynamics, precipitation, and evaporation. Due to the competing uses (agricultural, ecology and water resources management) in this region, it is advisable to couple the natural and engineering sciences models with those from the socio-economical agent models in prototypes. Furthermore, detailed investigations on upscaling concepts in groundwater modeling, nitrate-problems in different hydrological compartments and the behavior of the involved agents (water suppliers, water users, farmers, politicians) with regard to water use and risk perception will be carried out.
  - The catchment of the **Ammer** in the alpine foreland. It has an altitude gradient of 1700 m and is ideally outfitted with instruments (3 precipitation radars, DWD-Station Hohenpeissenberg, Tourism-Center Oberammergau, complete GIS available)
    Here, the groups Tenhunen/Kastner-Maresch (plant ecology), Schneider/Mauser (hydrology/remote sensing), Wirth/Egger (meteorology), Braun/Kobus (water resources management groundwater), Bendix (precipitation) and Schmude (Tourism) will carry out detailed investigations on the coupling between vegetation and hydrology, remote sensing, scaling of hydrological processes, lateral flows, groundwater recharge, pastureland economics, land-use changes and tourism. Due to the excellent data base in agriculture, hydrology, ecology, remote sensing and water-resources management in this test area, the natural and engineering sciences prototype models will be coupled here. In addition, detailed investigations will be carried out regarding upscaling concepts in groundwater modeling, and the nitrate problems in different hydrological compartments. To do this, ground truth measurements will be carried out to the appropriate extent (see descriptions of the sub-projects), in order to obtain the data needed to validate the models at different scales.

The spearheaded development test areas are characterized by the fact that extensive data are available here and that in every area, at least one group already has detailed experience. The investigation areas were selected so that a wide range of different natural and anthropogenic factors are covered representatively.

The explained concept shows that extensive efforts have been made to set-up the essential dialogue needed between the scientists' groups on a solid and clearly organized basis. This is necessary for a project with such a strong integrative character to be able to run efficiently and however, to simultaneously limit the project to the justified necessities. Overall, Tab.5 shows the temporal course of the various communication activities in GLOWA-DANUBE:

Event	Q1 year 1	Q2 year 1	Q3 year 1	Q4 year 1	Q1 year 2	Q2 year 2	Q3 year 2	Q4 year 2	Q1 year 3	Q2 year 3	Q3 year 3	Q4 year 3
Integrat.-Workshop		X 1 week				X 1 week				X 1 week		
Work-gr.-Workshop	X	X	X	X	X	X	X	X	X	X	X	X
Status-Workshop				X				X				X
Meeting Coodina-tion gr.	X		X		X		X		X		X	

Tab.5: Overview of the common events in GLOWA-DANUBE

Organizational Structure of the Project

GLOWA-DANUBE will be carried out within the framework of an expert network of universities, which is setup by the scientist groups of the involved universities. This is a new approach and the necessary university communication, decision, and administration structures have to be created and developed. To achieve the ambitious goals set forth by GLOWA-DANUBE, two areas with solid organizational structures are needed:

1. **Autonomous administration of the project:** The autonomous administration of the project will be characterized by the following structures:
   At the Ludwig-Maximilians-University an interdisciplinary *"Center for Integrative Global Change Research"* will be founded. The goal of this center will be to support the integrative, and thus interdisciplinary, approaches in global change research and to ensure its sustainable development. One task of this center will be to administrate the GLOWA-DANUBE project.
   All decisions that involve GLOWA-DANUBE will be met with a majority vote in the coordination group, which will have the following members:
   - A representative from each core group from the universities LMU Munich, Univ. Bayreuth, Univ. Stuttgart, and Univ. Freiburg (see Tab.1).
   - Two representatives from the bridge groups (see Tab.2).
   - The coordinator from GLOWA-DANUBE, unless he/she is a representative from one of both groups.

   The coordination group will meet at least twice a year.

2. **Communication, reporting regulations, and quality control:**
   here, via the self-evident installation of the given technical and organizational possibilities through the internet (Chat-Rooms, FTP-Server, etc.), two things have priority:
   - **internal communication and continued education.**
     The scientist groups involved in GLOWA-DANUBE require a fixed structure of workshops, colloquia, and bilateral expert events. To this end, the following events are planned annually:
     - 3 specialized-colloquia, held alternately by the various disciplines,
     - 2 specialized workshops for networking the separate sub-groups,
     - 1 week-long workshop with all scientists in the project to promote integration
   - **internal as well as external reporting.**
     Set-up of two documentation series:
     - Technical documentation of the developed objects (each group agrees to deliver this documentation, as a first draft, not later than after 2/3 of the project period in an agreed upon and comparable format),
     - Technical documentation of the ascertained data and the underlying data structures

- Scientific documentation of the developed scenarios as well as the targeted scientific results

3. Knowledge Transfer and Human Capacity Building:

It is very important that the models developed in GLOWA-DANUBE be quickly and competently circulated in the scientific community. The new international course of studies at the University of Stuttgart ”Water Resources Engineering and Management” will serve as a founding pillar. In the framework of this infrastructure, the educational forum GLOWA will be developed with a wide range of continued and advanced educational courses. It will consist of the following components:

- **Seminars** will serve as interdisciplinary education and to circulate the expert basis given by the doctoral candidates and co-workers involved in GLOWA-DANUBE. They will promote the dialogue and interdisciplinary communication, which is indispensable for such interdisciplinary research. There will be two types of seminars:
  Module 1: Expert teaching
  Module 2: Scientific information exchange.
- **Short courses** held by GLOWA-DANUBE-Partners and/or by guest professors within the framework of the Stuttgart Program ”Water Resources Engineering and Management (WAREM)” or the Bayreuth Program ”Ecosystem Management”.
- **Lectures** with GLOWA-DANUBE-agents and/or guest scientists.
- Provision of internationally **qualified co-workers** for GLOWA-DANUBE working groups.
- In order to sustainably anchor research at the universities, during the second phase of the project within the framework ”Center for Integrative Global Change Research”, LMU Munich plans to establish an **international Master’s degree program** specially fitted to integrative Global Change questions and problems.

4. The external accompaniment of the project

In order to accompany the progress of the work and to be able to incorporate suggestions as early as possible, status colloquia with an external circle of experts will be carried out. The circle will be set-up with experts from the scientific, economic, and administrative communities and financial sponsors. Status colloquia will be held once a year. Their results will be recorded and the participants informed.

The described task will be coordinated by the ”Center for Integrative Global Change Research”.

Expected Performance

GLOWA-DANUBE is breaking new ground in many areas. It shall be critically illuminated here, as to which risks are involved and how they will be encountered with the framework of the project. In the following areas, the expectations of success of GLOWA-DANUBE are critically contemplated from the stand point of the project partners:

- *Integration of the expert disciplines*
  This area is of central importance for the success of the project. According to the project partners, there are three reasons that speak for success in this area: 1) the agreement to a common raster-oriented model structure between all involved project partners (*natural and social sciences*!), 2) the clear identification of common interfaces between the project partners before the start of the project, 3) the establishment of a hierarchical communication structure between the groups with bilateral cooperation, working groups, workshops, and colloquia.
- *Development of integration methods and techniques in modeling water flow based on distributed objects in the network with CORBA and formalization of the multi-disciplinary modeling with the Meta-Modeling Language UML.*

From the project partners' point of view, this is essentially the only possible approach, if the project is to be conceived as a distributed expert network and developed on the basis of re-useable, refineable, and documented sub-models. The risks in this approach lie less in the possibilities of the applied industry standards than in the possible limitation of the acceptance through the project partners. The applied industry standards are open, exactly designed and coded (and not, as often at the universities, patched "with fast needles"), excellently documented and expandable. Extensive experience about their applications in industry is available (Jones, C. (1996)). These show that successful software projects in the magnitude such as this one, are characterized by items such as agreements as to interfaces, determined mutual check-ups, exactly defined quality-checks and clearly assigned areas of responsibility. The specified structure of the one-week workshops, working group meetings, and bilateral cooperation take these requirements into account. At that, milestones and deliverables will be stipulated between the project partners. Essential for the success of the project will be the motivation of the groups to carry out these discussions and to accept and commonly design a uniform, formalized Meta-Modeling language. Due to this, the start of the networked development will be in the areas of hydrology and plant ecology (where it is easiest) and groundwater. The network modeling prototype created, shall convince the other project partners of the usefulness of the development during the first workshop. Therefore, the expectation of success is set at high to very high.

- *Transition in the process description from microscale to mesoscale and vice versa*
  This transition is necessary, in order to develop mesoscale models and to interpret the results at the microscale. This is common to almost all sub-projects as a transversal theme. Transition is not easy due to the complex nature of the investigated objects. However, work in this area is supported to a large degree by models of sub-processes already developed in the group, by successes achieved in the group in upscaling from microscales to mesoscale and by the already mentioned commonly agreed upon raster-based model structure, that make successful scaling-techniques relatively easily transferable. Due to this, it is to be expected that in this project a large step towards a common description of the processes in the natural and social sciences will be possible.
- *Use of remote sensing*
  Using remote sensing in such projects is not yet common, but from the viewpoint of the project partners very important especially with regard to the transferability of the developed methods to other regions. Research in the field of information retrieval from remote sensing data has made great advances in recent years. Thus, stable algorithms to determine a multitude of land surface and atmospheric parameters now exist. These shall be applied in the project. At the same time, new and improved possibilities will become available during the course of the project with the new sensors of the next generation (TERRA, AQUA, ENVISAT, METEOSAT 2nd Generation). The risk of a false start of these mentioned systems exists. In such a case, the data from the existing sensors (AVHRR, SeaWifs, MOS, METEOSAT) will be used. Even with these data, new procedures to assimilate remote sensing data into integrative models can be developed, even if the expanded possibilities cannot be used at first. Thus, the expectation of success is rated good in this area.
- *Set-up and operation of an expert network oriented primarily at the university level*
  the network of the project consists in its absolute majority of university groups. This corresponds with the call for proposals and is politically wanted research. The groups are deliberately filled with young academics (habilitating academics and newly habilitated). A possible risk in this is the quick depletion of personnel in the project in its thought-of structure due to successful appointments as university professors. The project partners see this as only a small risk due to three reasons: 1) it is in the sense of an expert network, to use modern communication possibilities to communicate and cooperate beyond

the involved places (the expert network only gets larger), 2) the necessity to locally coordinate the work and to maintain the contacts (even with an appointment, the Danube cannot be transferred!) is taken into account since almost all groups are co-led by a permanent scientist and a young academic, 3) the sustainable development of the expert network will benefit by the planned founding of the Center for Integrative Global Change Research. This center will have steady personnel and can ensure the necessary continuity of the administration of the project.

Literature

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Jones, C: Patterns of Software System Failures and Success, Int. Thomson Computer Press, 1996