AN INTEGRATED MODEL FOR CONJUNCTIVE SIMULATION OF HYDROLOGICAL PROCESSES AND WATER RESOURCES MANAGEMENT IN RIVER BASINS – Part 1

European Geosciences Union (EGU) General Assembly, Vienna, Austria, 25 - 29 April 2005

Session HS4: ***Incorporating hydrological processes knowledge into catchment modelling***

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What is HYDROGEIOS?

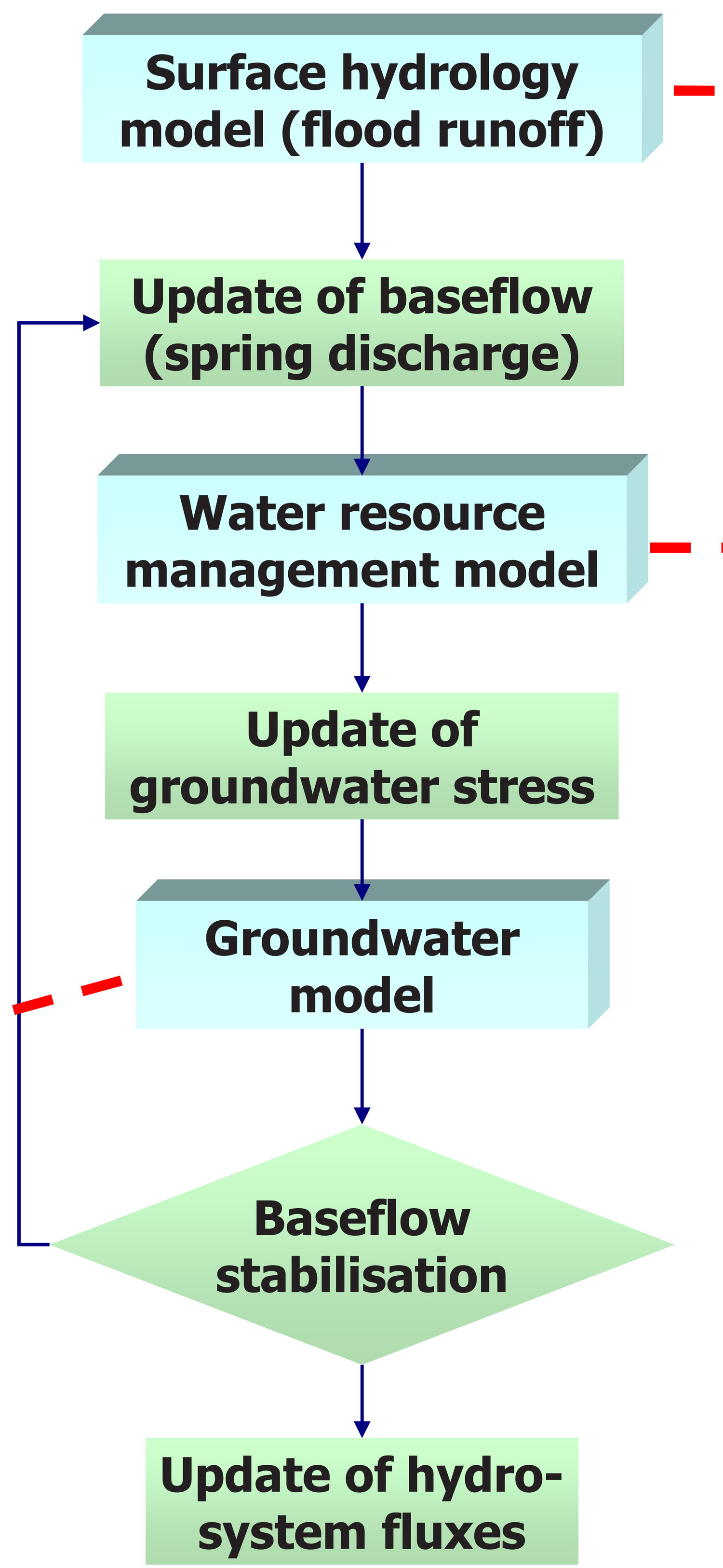
HYDROGEIOS is a **GIS-based** application, suitable for complex hydrosystems, where natural processes are significantly affected by human interventions. It integrates a **conjunctive** (surface and groundwater) **hydrological model**, based on a semi-distributed approach, within a **systems-oriented management scheme**, to ensure a faithful representation of hydrological mechanisms and, hence, a rational water management policy. It provides tools for **automatic parameter estimation**, based on multiple error criteria and a robust optimisation method, adapted for both single and multiobjective calibrations.

Objectives

- Establishing a physically-based approach while keeping a parsimonious structure, by conceptually relating the hydrological responses of a watershed with its geomorphological and physiographic characteristics.
- Taking into account all available spatial and hydrological data.
- Understanding the main physical mechanisms along a river network, and their interactions under a specific hydroclimatic scenario or management policy.
- Assessing the actual surface and groundwater yield at various control sites.

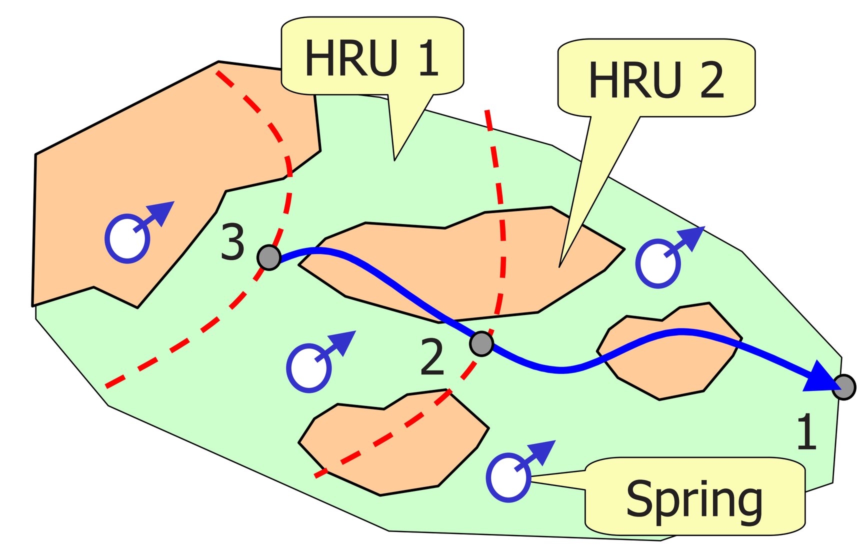
Input data

- Raw geographical data: terrain model, soil properties (e.g., permeability), land cover, monitoring stations
- Surface hydrology components: hydrographic network (river nodes and segments), sub-basins, hydrological response units (HRUs)
- Groundwater components: aquifers, springs, boreholes
- Water management components: channels, pipes, demand sites, irrigated areas, borehole groups, water uses and priorities, operational costs and constraints
- Time series: precipitation & potential evapotranspiration (for each sub-basin), water needs, control series (discharge measurements, observed aquifer levels)
- Scenario data: computational parameters for simulation and optimisation procedures, error criteria for calibration



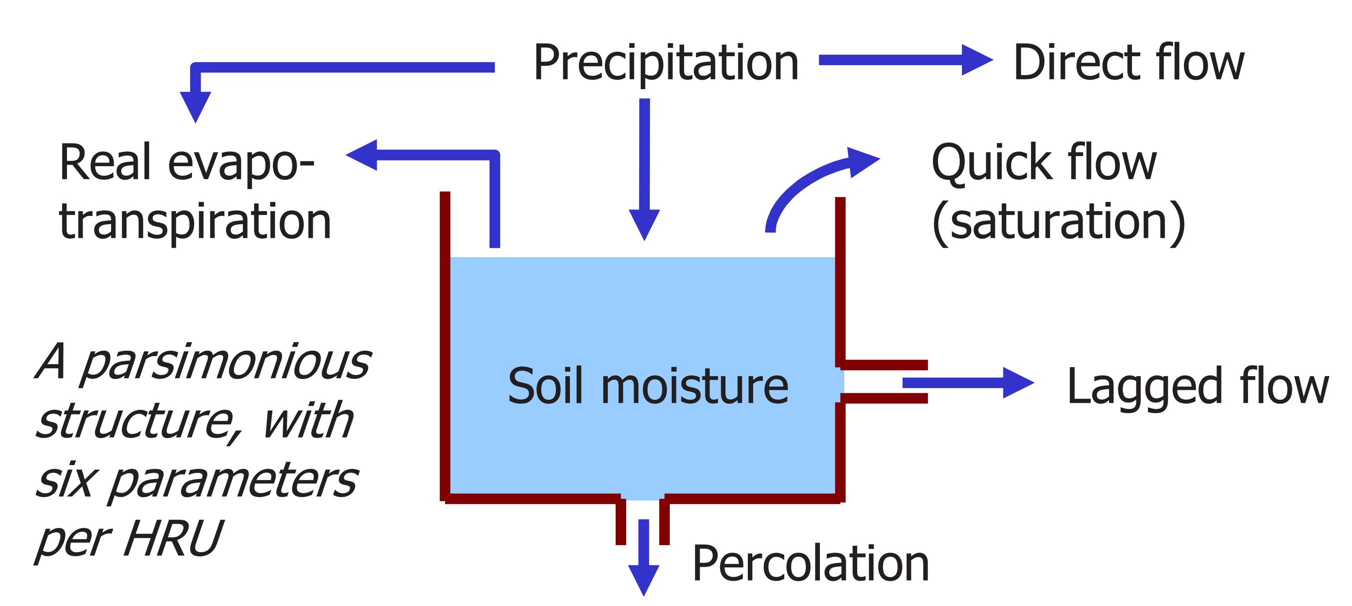
Simulation flowchart

Surface hydrology processes

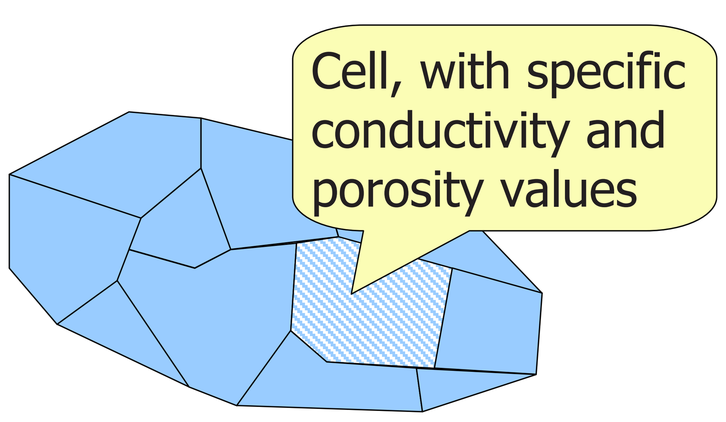


Hydrological response units (HRUs): spatial components that correspond to areas with homogenous hydrological characteristics

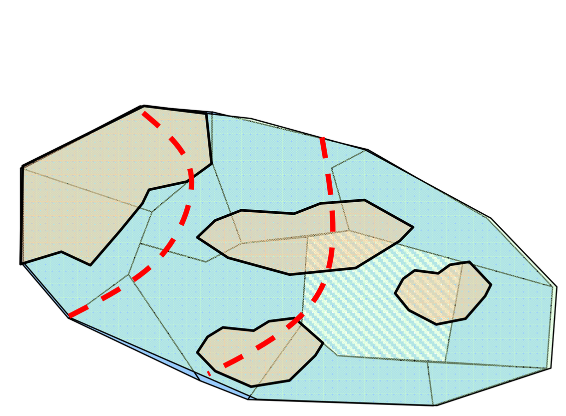
For each sub-basin and HRU combination, a conceptual **soil moisture accounting model** runs to compute the transformation of precipitation to real evapotranspiration, deep percolation and flood runoff; the latter, together with the estimated spring runoff (baseflow) is directly transferred to the downstream node of the corresponding basin.



Groundwater hydrology processes

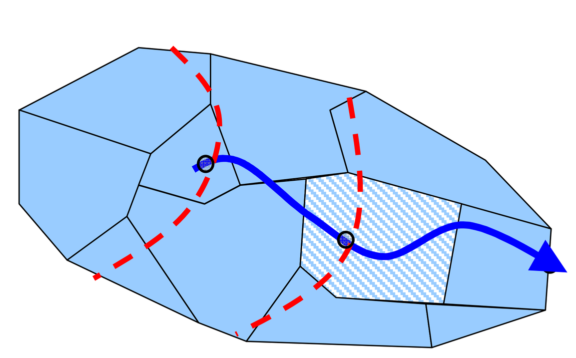


Groundwater cell layer

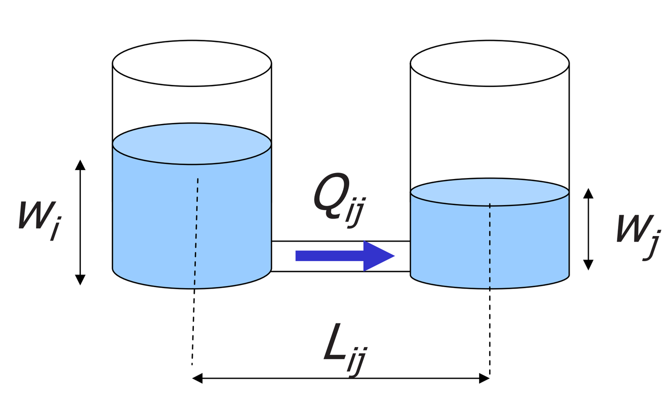


Union of cell, sub-basin and HRU layers

A Darcian multi-cell scheme is established, based on a non-rectangular discretisation of the groundwater system.

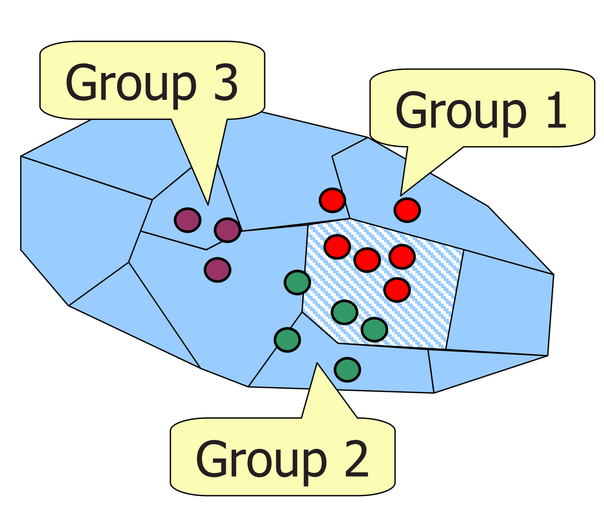


Intersection of cell and river network layers



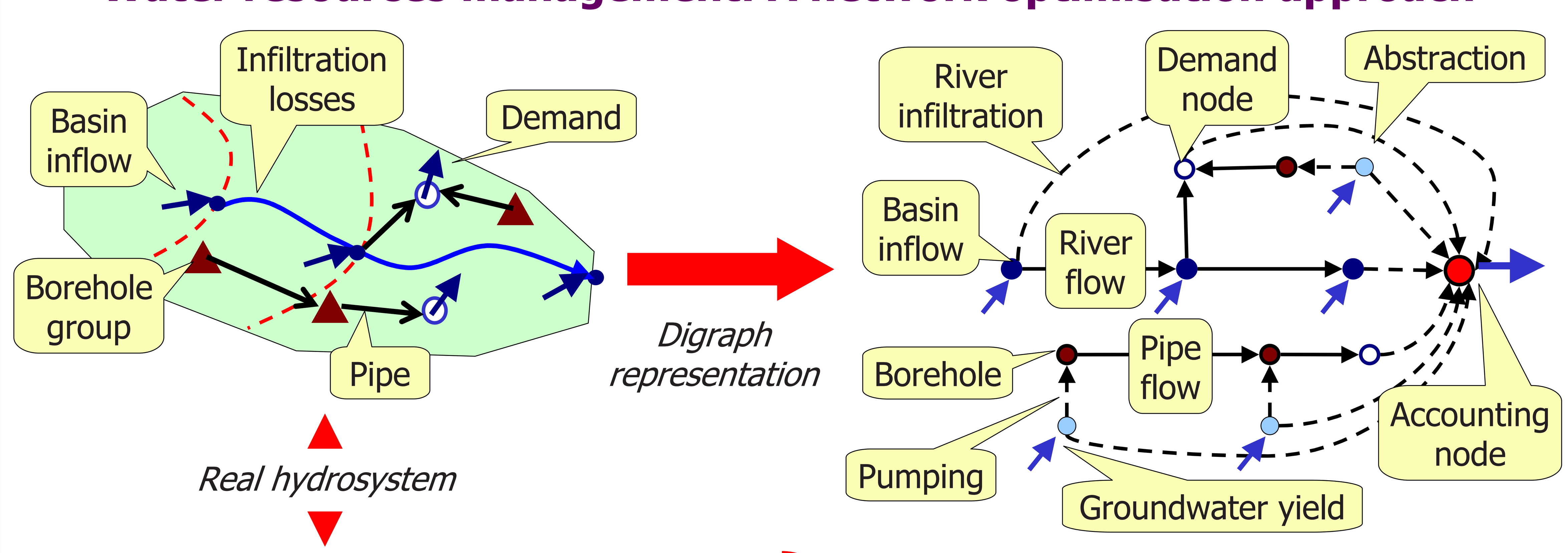
Each cell is represented as a conceptual tank, of which the stress components are: (a) **percolation** from each sub-basin and HRU combination, (b) **infiltration losses** from each river segment, and (c) **pumping** from each borehole.

Springs are modelled as tanks with very large base.



Intersection of cell and borehole layers

Water resources management: A network optimisation approach



- basin and spring runoff, assumed point supply
- groundwater yield (= pumping capacity)
- water needs, constraints and priorities
- real capacities and unit cost values of hydrosystem components

Calculation of all **hydrosystem fluxes**, by transforming real components to digraph components, assigning virtual inflows, costs and capacities, and solving a LP problem

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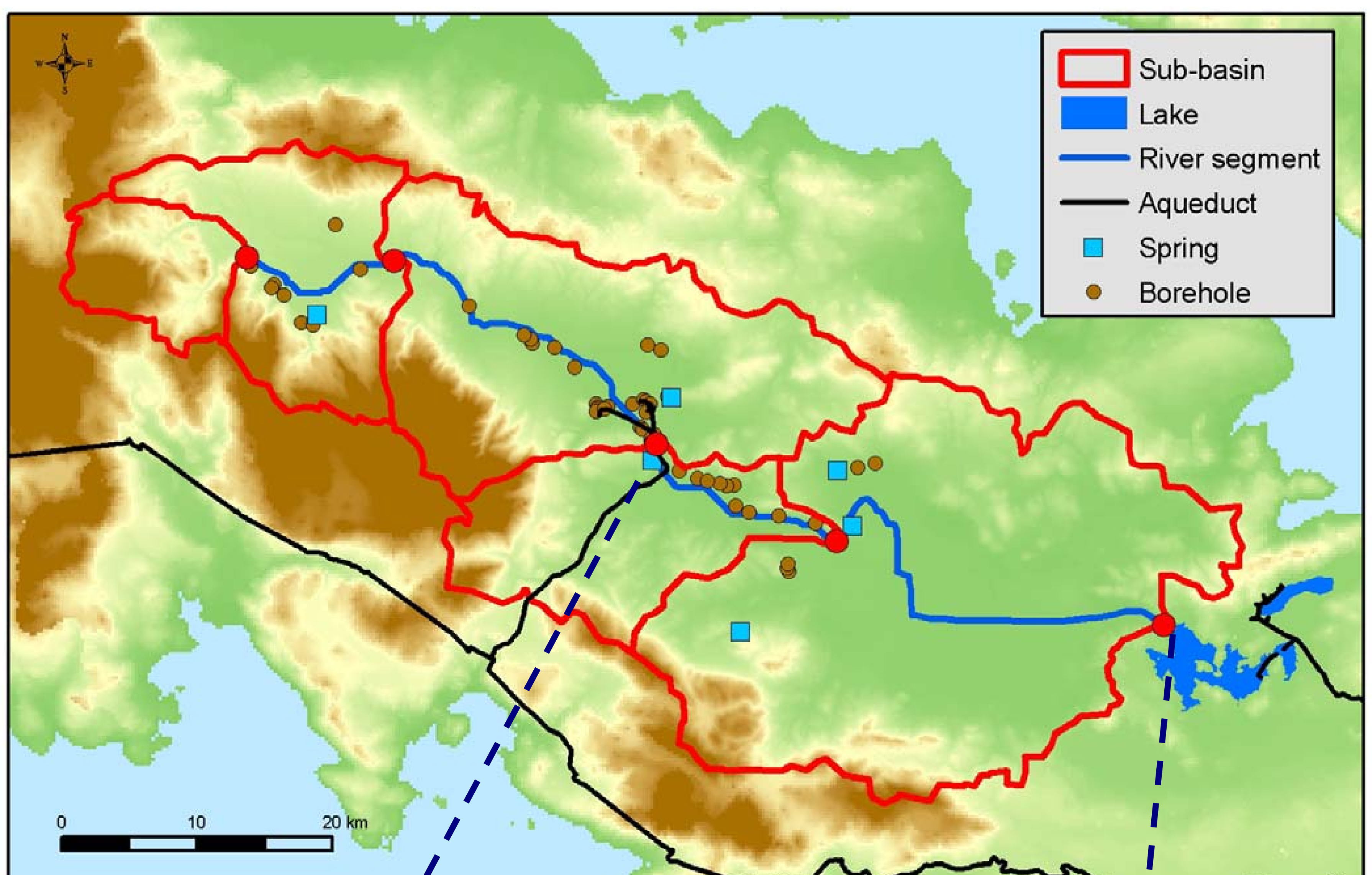
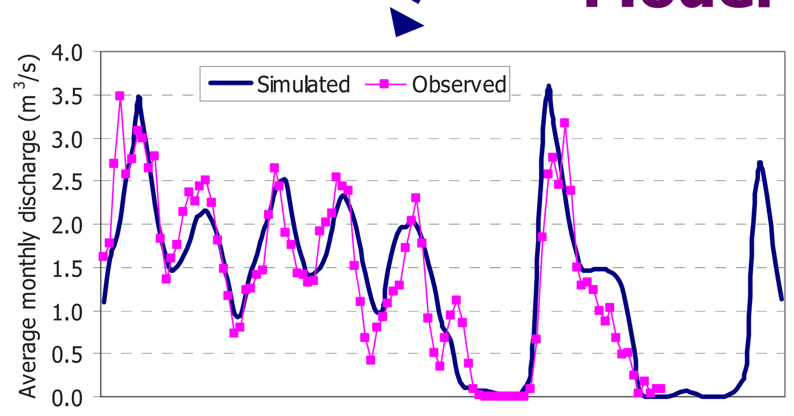
Case study: The Boeoticos Kephisos river basin

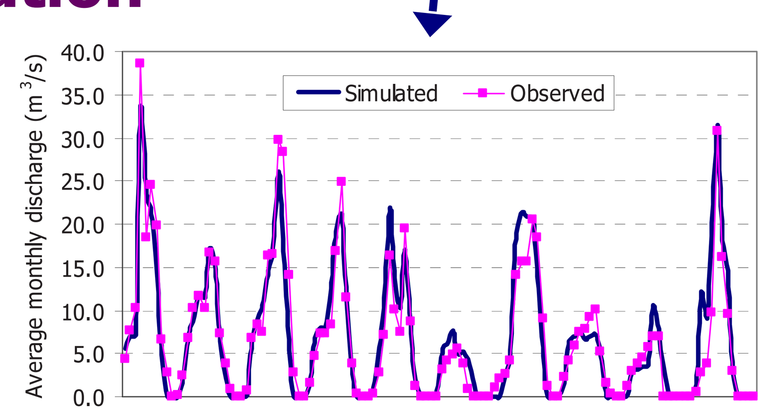
- Watershed area: 1955.6 km^2 (the largest of the Eastern Sterea Hellas water district)
- Altitudes: 469 m (average), 2400 m (maximum)
- Geology: heavily karstified limestones (mountainous areas), alluvial deposits (plain areas)
- Hydrographic network: a main branch of length 100 km; last 35 km segment is an artificial channel, diverting flows to the neighbouring Lake Hylike (the basin has no physical outlet to the sea)
- Hydrology: mean annual precipitation 765 mm, mean annual runoff 172 mm
- Groundwater: due to the karstic background, significant percentage (~50%) of runoff is baseflow, arising from large springs in the upper and middle part of the basin; unknown amount of groundwater is conducted to the sea
- Water uses: (1) abstractions from both surface and groundwater resources for irrigation (220 hm^3/year); (2) abstractions from Lake Hylike and water supply boreholes lying in the middle part of the basin, directed to Athens



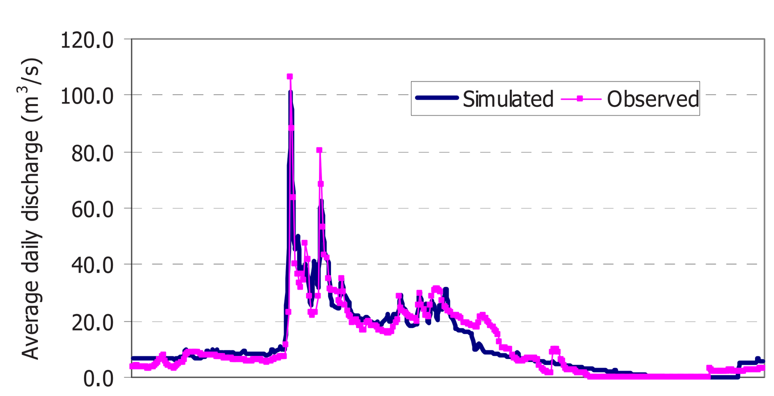
Model calibration



Mavroneri springs



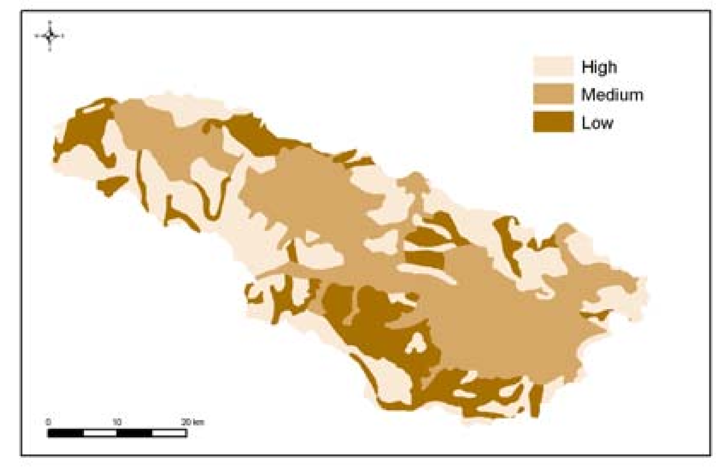
Basin outlet (monthly simulation)



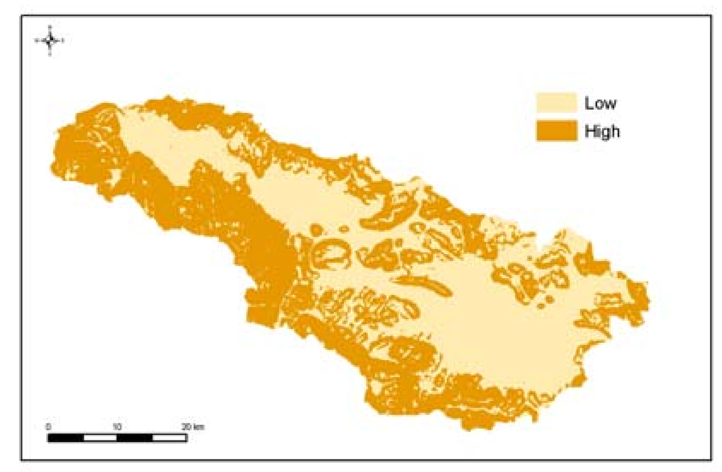
Basin outlet (daily simulation)

- Model schematisation: 5 sub-basins, 6 HRUs, 30 groundwater cells
- Control period: 10-years (1984-1994), for monthly and daily simulation time steps
- Calibration data: daily discharge series at the basin outlet, sparse (1-2 per month) flow measurements along the river and downstream of the main karstic springs
- Objective function: formulation of a weighted performance measure, based on multiple responses and multiple fitting criteria
- Optimisation method: evolutionary annealing-simplex (single- and multiobjective)

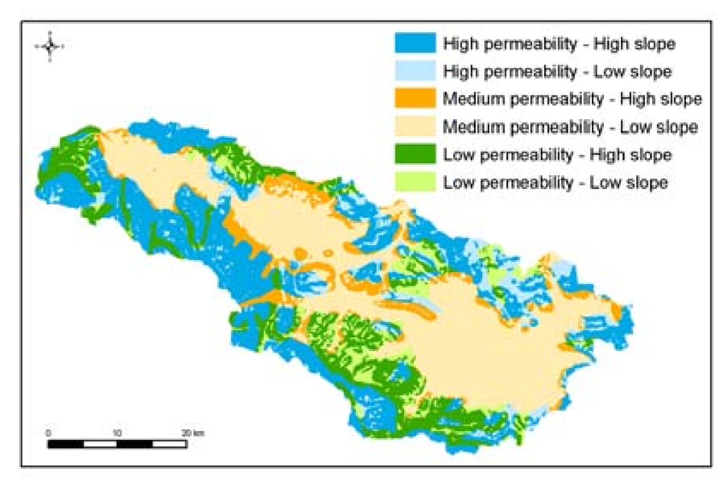
Surface hydrology



Permeability class

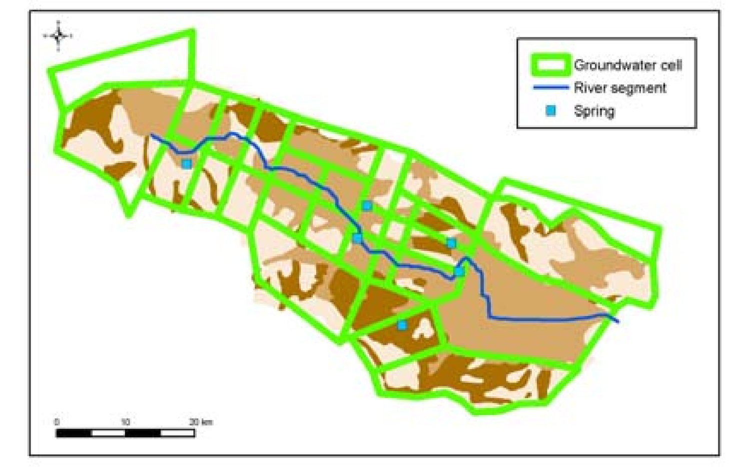


Slope

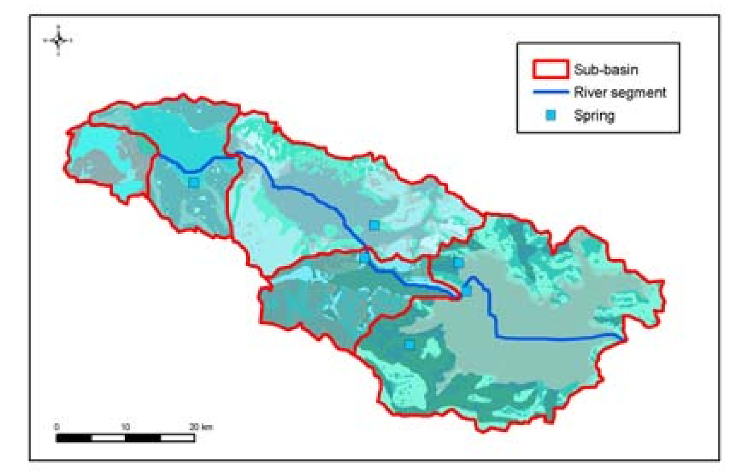


Hydrological response units

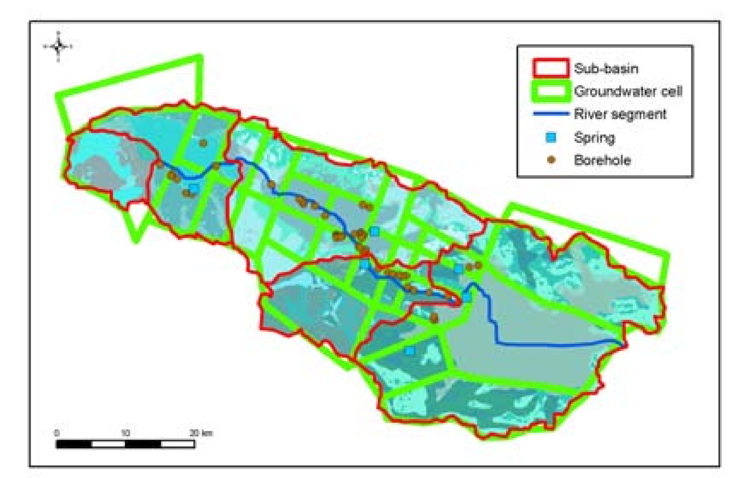
Groundwater hydrology



Multi-cell model schematisation



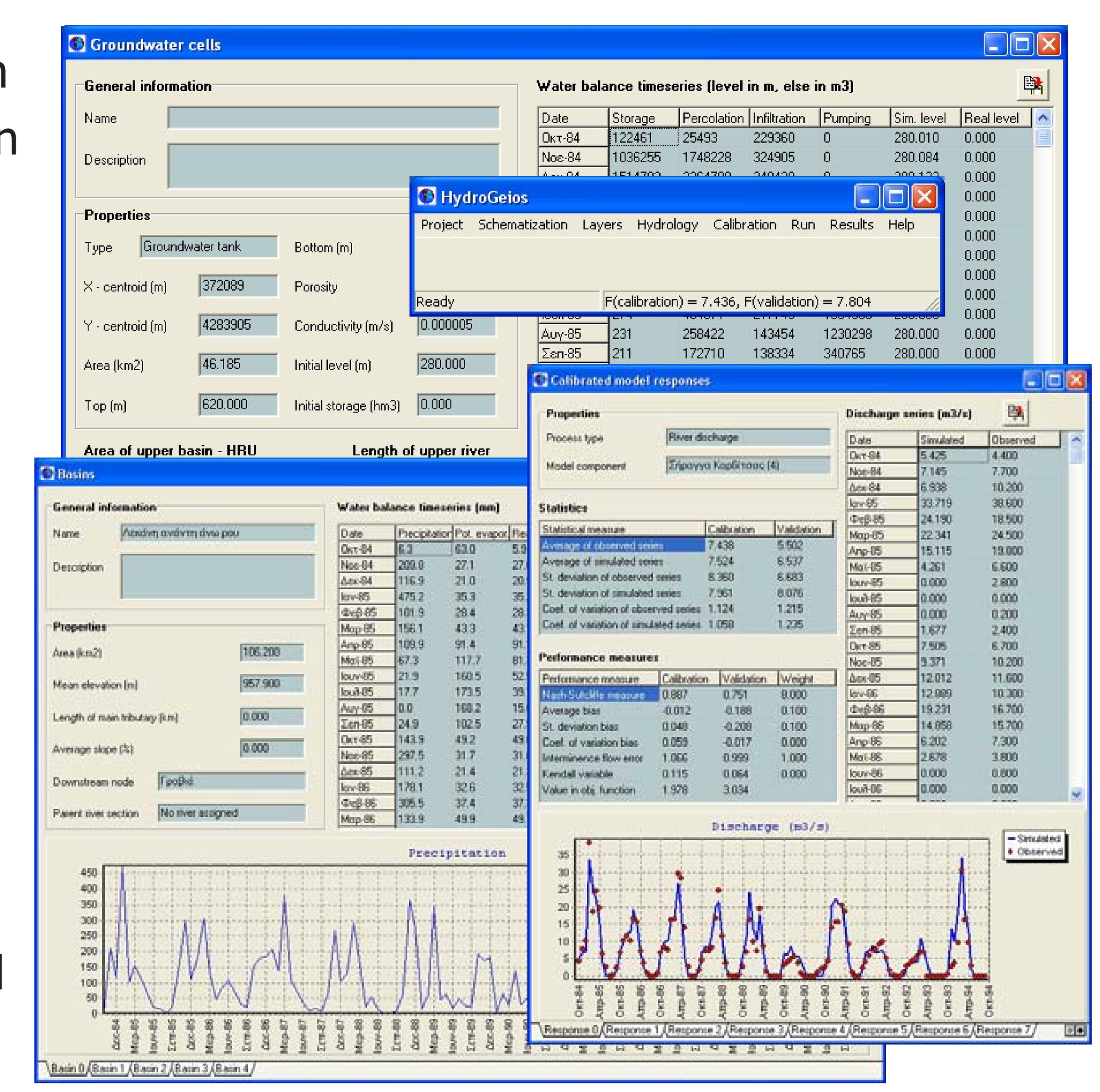
Sub-basins and HRUs union



Union of groundwater layers

HYDROGEIOS: Software implementation

- Monthly or daily simulation
- Flow routing procedures, in case of daily time steps
- Multiple goodness-of-fit criteria, for discharge and groundwater level series
- Automatic calibration of selected parameters or groups of parameters
- Parameter uncertainty assessment, through multiobjective techniques
- Detailed (step-by-step) water balance for all hydrosystem components
- Visualisation of results and export to spreadsheets



Acknowledgments – Contact info

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Project web page: http://www.odysseusproject.gr/

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