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

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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.

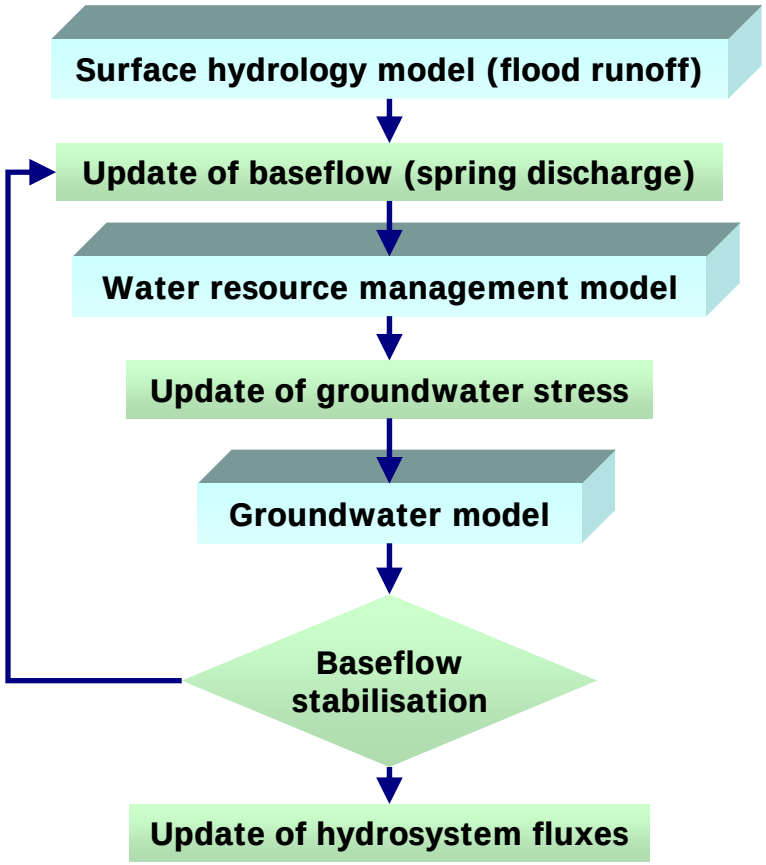
Objectives

- 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.

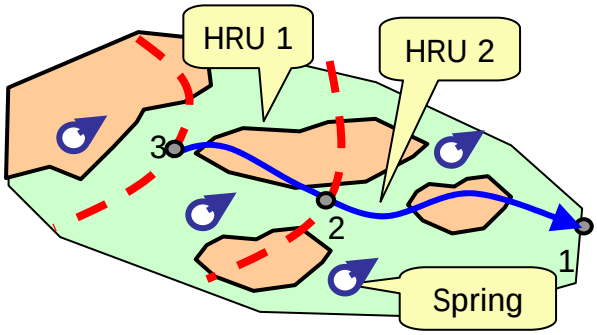
Input data

- 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

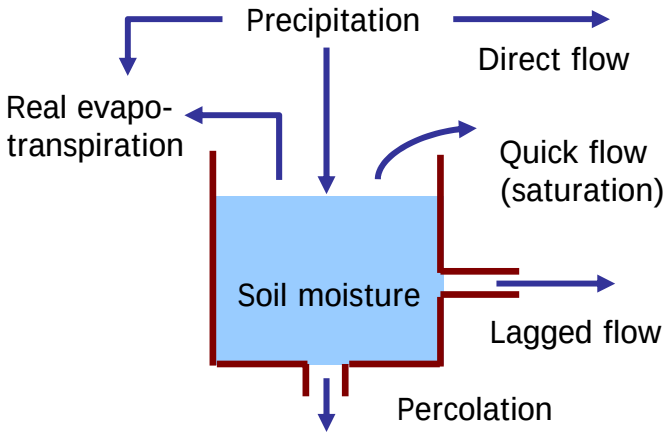


Surface hydrology processes



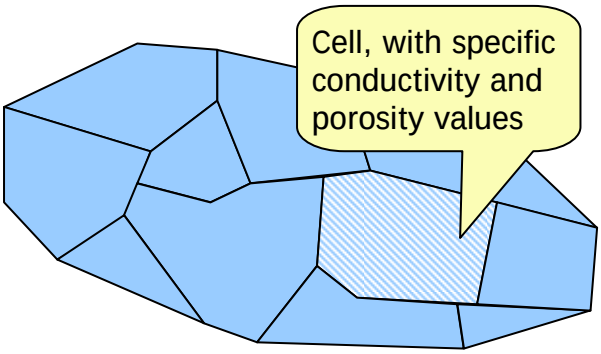
For each sub-basin and HRU combination, a conceptual **soil moisture accounting model** runs to compute the transformation of precipitation to real evapotranspiration, deep percolation and flood runoff; the latter, together with the estimated spring runoff (baseflow) is directly transferred to the downstream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

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

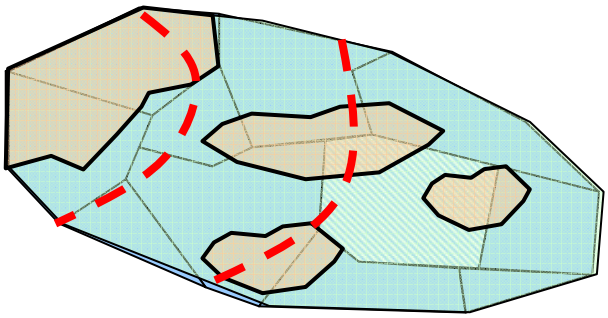


A parsimonious structure, with six parameters per HRU

Groundwater hydrology processes

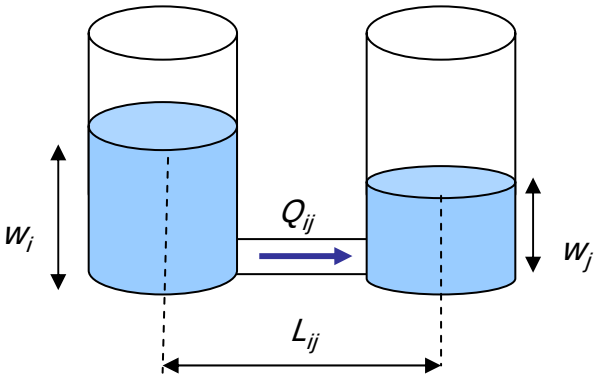


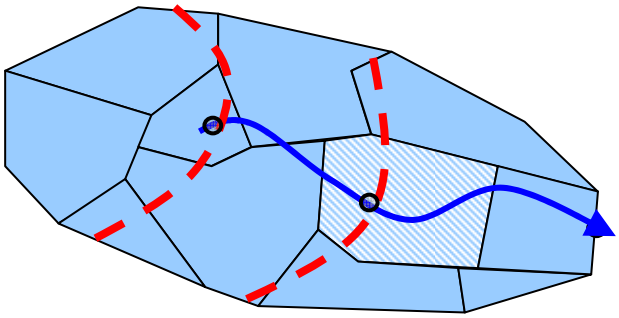
Groundwater cell layer



Union of cell, sub-basin and HRU layers

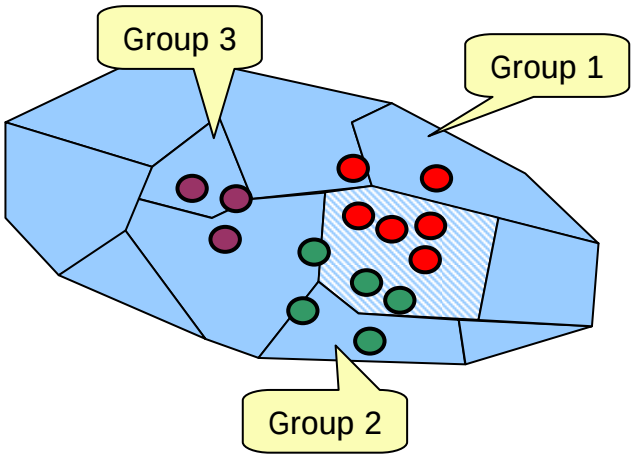
A Darcian multi-cell scheme is established, based on a non-rectangular discretisation of the groundwater system.





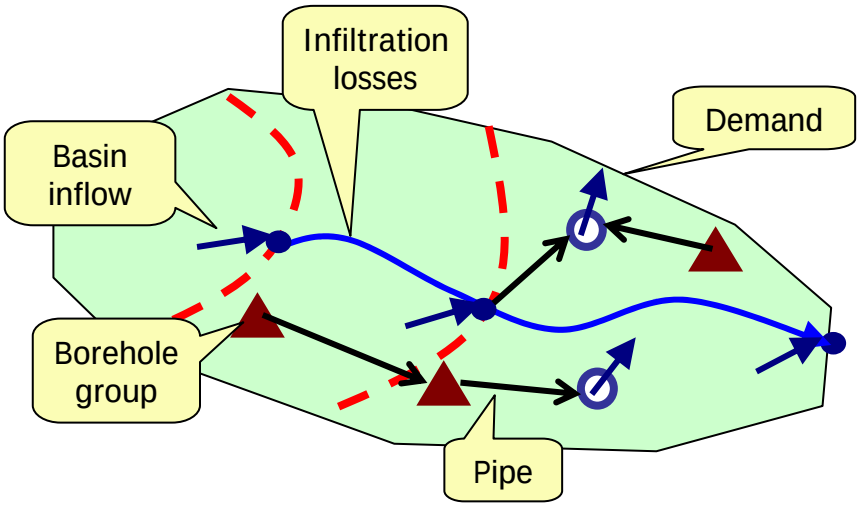
Intersection of cell and river network layers

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.

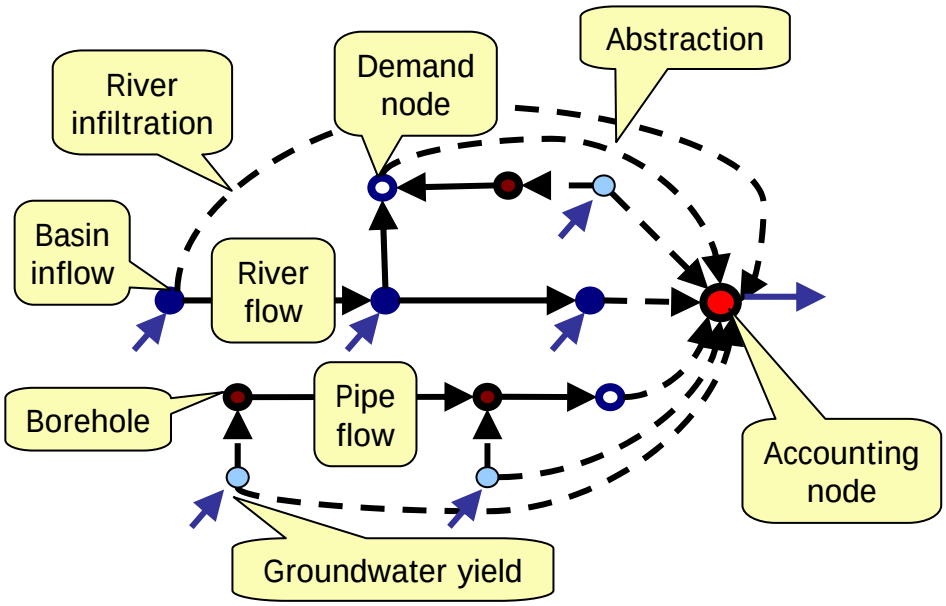


Intersection of cell and borehole layers

Water resources management: A network optimisation approach



Real hydrosystem



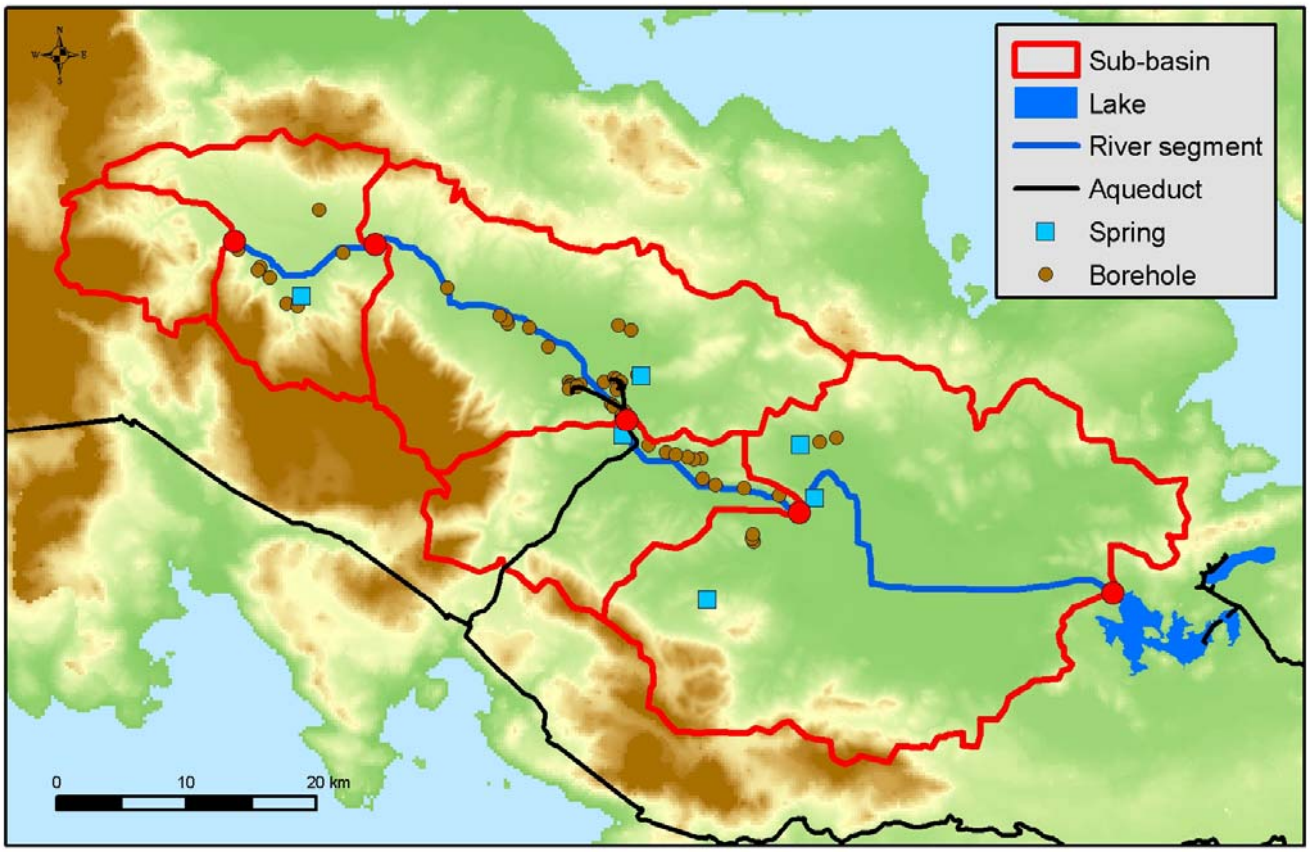
Digraph representation

- 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

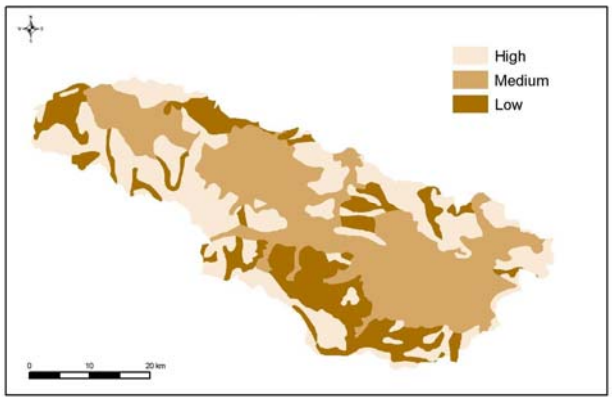
Calculation of all **hydrosystem fluxes**, by transforming real components to digraph components, assigning virtual inflows, costs and capacities, and solving a LP problem

Case study: The Boeoticos Kephisos river basin

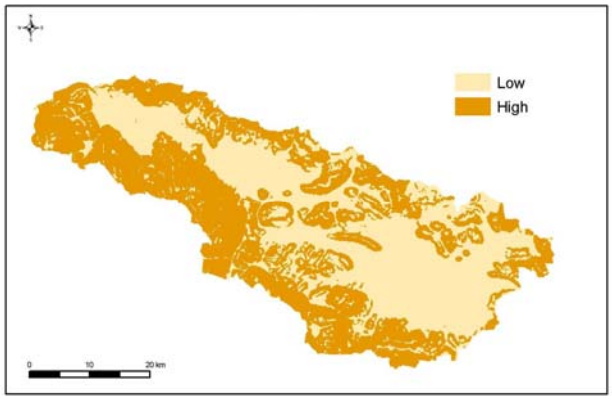
- Watershed area: 1955.6 km^2 (the largest of the Eastern Sterea Hellas water district)
- Altitudes: 469 m (average), 2400 m (maximum)
- Geology: heavily karstified limestones (mountainous areas), alluvial deposits (plain areas)
- Hydrographic network: a main branch of length 100 km; last 35 km segment 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



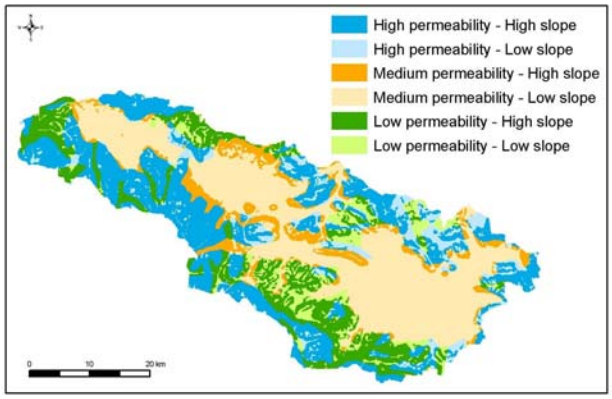
Surface hydrology



Permeability class

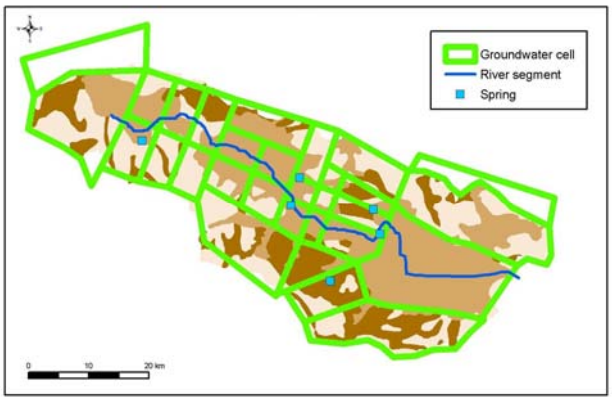


Slope

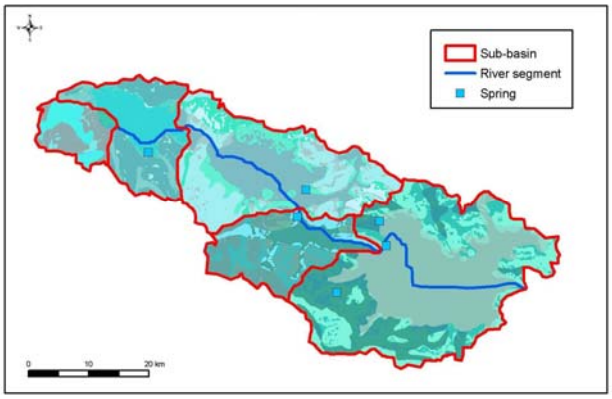


Hydrological response units

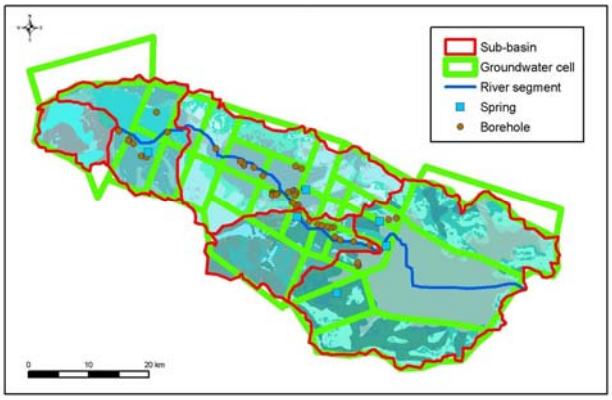
Groundwater hydrology



Multi-cell model schematisation



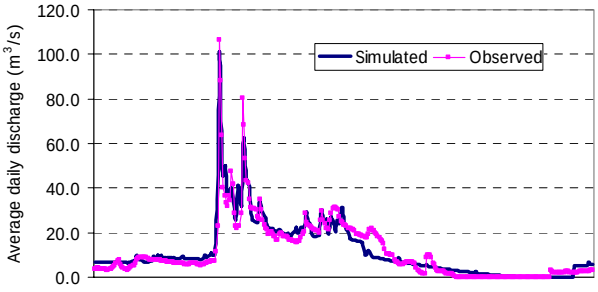
Sub-basins and HRUs union



Union of groundwater layers

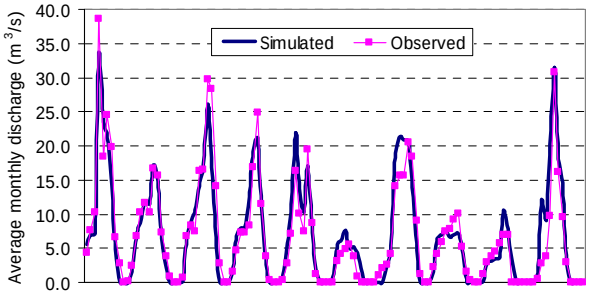
Model calibration

- 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

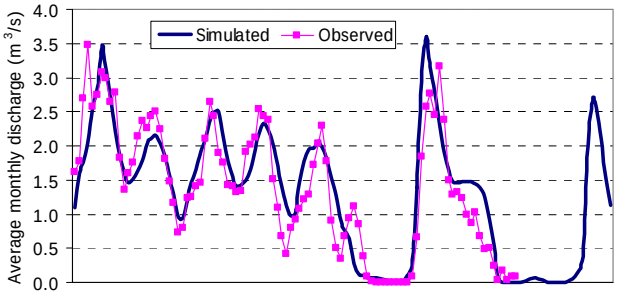


Basin outlet (daily simulation)

- Objective function: formulation of a weighted performance measure, based on multiple responses and multiple fitting criteria
- Optimisation method: evolutionary annealing-simplex (single- and multiobjective)



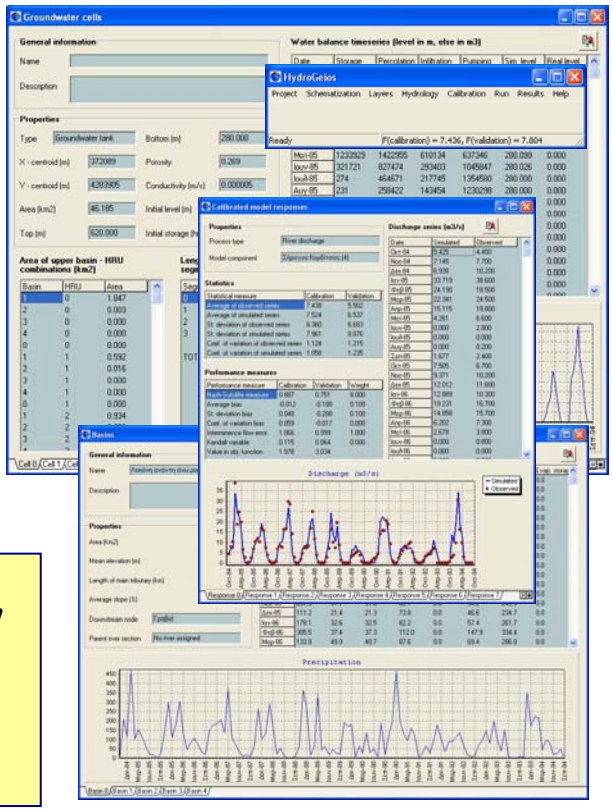
Basin outlet (monthly simulation)



Mavroneri springs (monthly simulation)

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



HYDROGEIOS is developed within the project "*ODYSSEUS: Integrated Management of Hydrosystems in Conjunction with an Advanced Information System*".

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

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