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Geoinformation of Environment, 8-10 April 2013, Paphos, Cyprus*

Session title: “Natural Hazards - Floods & Seismic”

Hydro-meteorological network for flood monitoring and modeling

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1. Introduction & motivation

- There exist hundreds of small- to medium-size (i.e. up to $\sim 250 \text{ km}^2$) Mediterranean basins (particularly in Greece and Cyprus), which are typically affected by **flash floods**.
- The majority of them lack measuring infrastructure (especially, continuous flow-gauging stations), which is essential for both **flood monitoring** and **modeling**.
- Due to the lack of flow information are preferred rather simplistic or outdated approaches for **ungauged basins**, with questionable physical consistency, since most of them do not consider local peculiarities (hydroclimatic, geomorphological).
- In order to provide a consistent framework for flood design and to ensure realistic predictions of the flood risk, which is key issue of the **2007/60/EC Directive**, it is crucial to improve the monitoring infrastructures, by taking advantage of modern technologies for remote control and data management.
- In this context, we have recently developed a **telemetry-based hydro-meteorological network** that comprises automatic stations in four pilot river basins, which is linked to and supported by relevant software.
- The **software system** includes:
 - a web-based application for storage, visualization and management of spatial and hydro-meteorological information (ENHYDRIS);
 - a software for hydro-meteorological data analysis and processing (HYDROGNOMON);
 - a modeling framework for flood simulation (HYDROGEIOS).
- The system is tested within a demonstration **case study**, implemented in one of the pilot river basins (Nedontas, Peloponnese).

2. The research program “Deucalion”

- **Full title:** Assessment of flood flows in Greece under conditions of hydroclimatic variability: Development of physically-established conceptual-probabilistic framework and computational tools
- **Partnerships:** (1) ETME Peppas & Collaborators S.A.; (2) Maheras Technical Office S.A., (3) National Technical University of Athens; and (4) National Observatory of Athens

<http://deucalionproject.gr/>

ΔΕΥΚΑΛΙΩΝ - Δίκτυο Δεδομένων ΔΕΥΚΑΛΙΩΝ

Σταθμοί Διαγράμματα ΑΜΣ Διαγράμματα ΑΥΣ Λεκάνες Χάρτης

Σταθμοί

Υδρομετρικοί

Μετεωρολογικοί

Τεχνικές εκθέσεις

Δημοσιεύσεις

Λογισμικά

ΔΕΥΚΑΛΙΩΝ – Εκτίμηση πλημμυρικών ροών στην Ελλάδα σε συνθήκες υδροκλιματικής μεταβλητότητας: Ανάπτυξη φυσικά εδραιωμένου εννοιολογικού-πιθανοτικού πλαισίου και υπολογιστικών εργαλείων

Το έργο ΔΕΥΚΑΛΙΩΝ αποσκοπεί στην ανάπτυξη φυσικά εδραιωμένων μεθοδολογιών μοντελοποίησης και πρόγνωσης των ισχυρών καταγλιών και των επαγόμενων πλημμυρικών φαινομένων, προσαρμοσμένων στις ιδιαιτερότητες των ελληνικών υδροκλιματικών και γεωμορφολογικών συνθηκών. Περιλαμβάνει την υλοποίηση ενός συνόλου ερευνητικών λεκανών, το οποίο περιλαμβάνει λεκάνας από την Ελλάδα και την Κύπρο που ήδη διαθέτουν αξιόπιστα και επαρκούς μήκους δείγματα μετρήσεων, καθώς και τρεις νέες πιλοτικές λεκάνας (με τις υπολεκάνες τους), όπου θα τοποθετηθεί κατάλληλος εξοπλισμός. Από την ανάλυση των δεδομένων πεδίου (υδρολογικών, μετεωρολογικών, γεωγραφικών) θα εξαχθούν φυσικά τεκμηριωμένες περιοχικές σχέσεις για την εκτίμηση χαρακτηριστικών υδρολογικών μεγεθών σχεδιασμού, και θα αναπτυχθούν υδρολογικά-υδραυλικά μοντέλα που θα ολοκληρωθούν σε ένα επιχειρησιακό σύστημα υδρομετεωρολογικής πρόγνωσης. Προβλέπεται ακόμη η προετοιμασία (υπό μορφή προσχεδίου για επιστημονική συζήτηση) ενός πλαισίου κριτηρίων σχεδιασμού και μεθοδολογιών εκπόνησης μελετών υδρολογίας αντιπλημμυρικών έργων.

Περίοδος εκτέλεσης: Μάρτιος 2011–Μάρτιος 2014

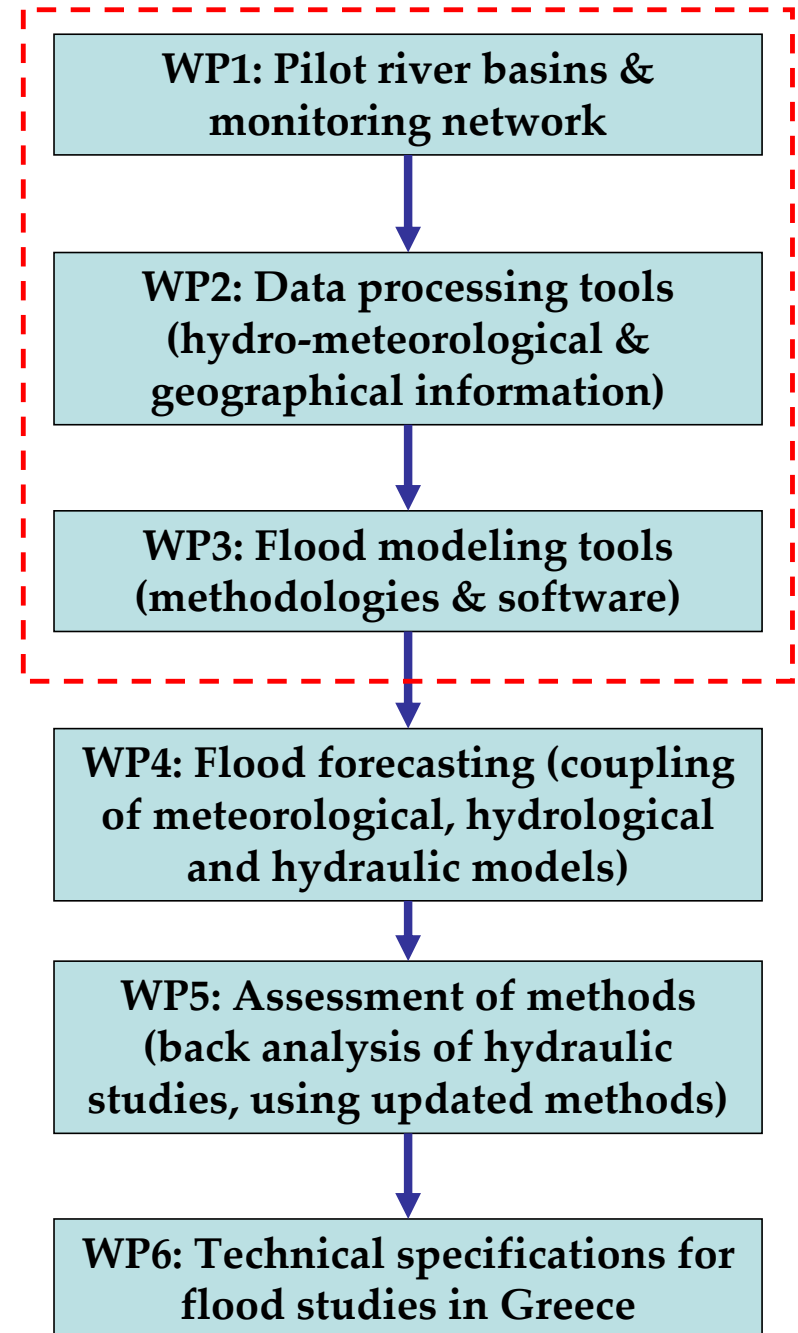
Προϋπολογισμός: €576 000 (€460 000 δημόσια δαπάνη)

Ανάθεση: Γενική Γραμματεία Έρευνας και Τεχνολογίας

Ανάδοχοι:

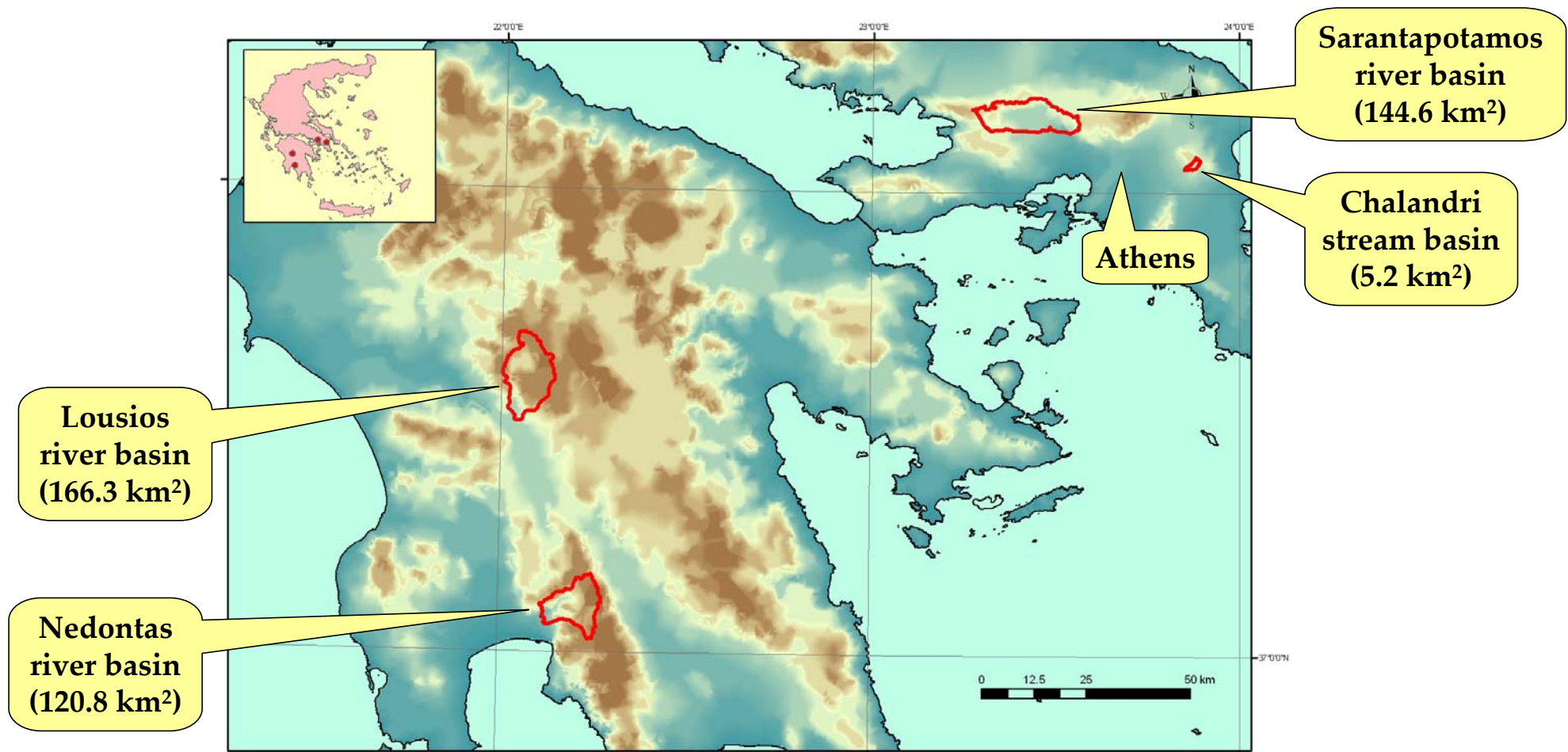
1. Γραφείο Μελετών ETME - Αντωνίου - Πέππας και Συνεργάτες
2. Γραφείο Μαχαίρα
3. ΕΜΠ, Τομέας Υδατικών Πόρων και Περιβάλλοντος
4. Εθνικό Αστεροσκοπείο Αθηνών

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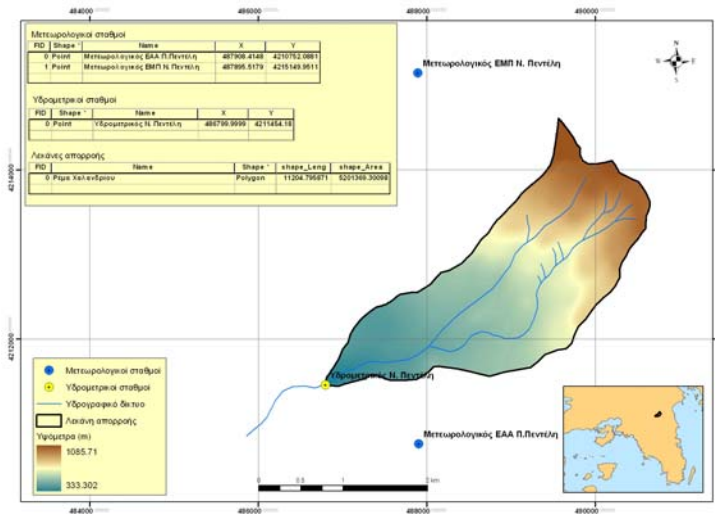


3. Telemetry-based monitoring network

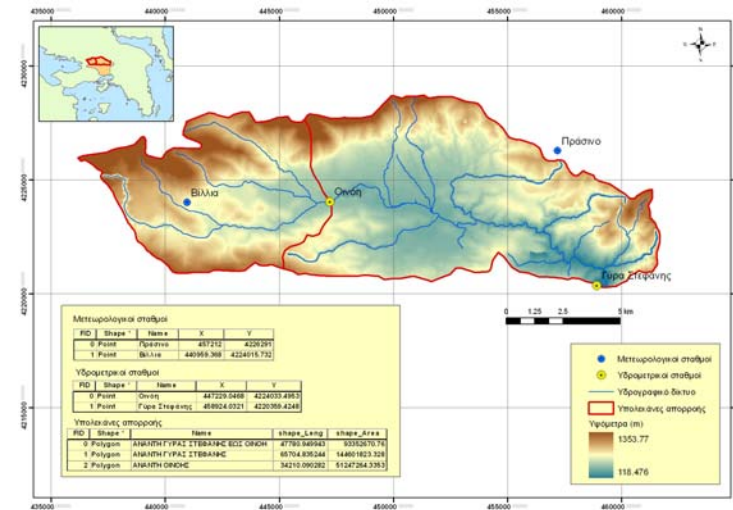
- **Network components:** 10 fully-equipped meteorological stations, 5 rain gauge stations, 8 automatic hydrometric stations
- **Spatial extent:** Four pilot river basins (two in Attica-Boeotia and two in Peloponnese), with areas ranging from 5.2 to 166.3 km²
- **Key specifications:** Automatic operation, low cost, reliability, preset time intervals, data logging, remote accessibility



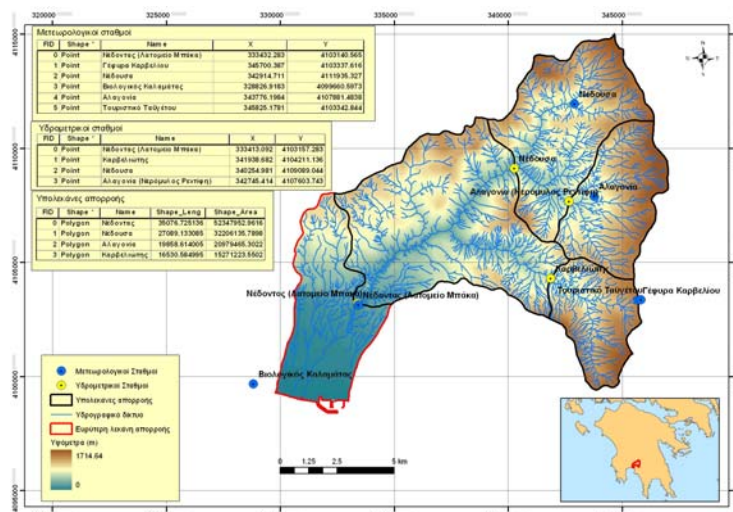
4. Basin characteristics



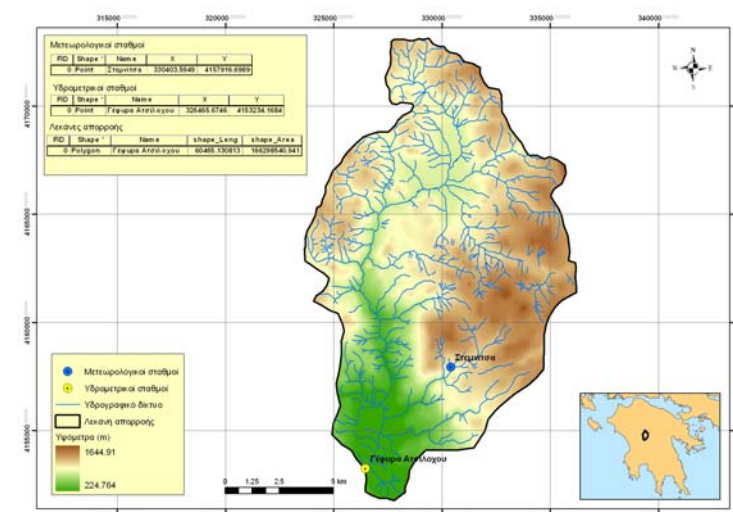
Chalandri stream: small-scale, sub-urban



Sarantapotamos: very low surface runoff, ephemeral flow, outflow to industrial zone



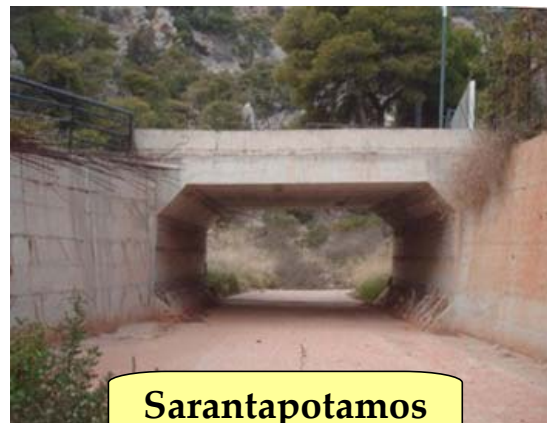
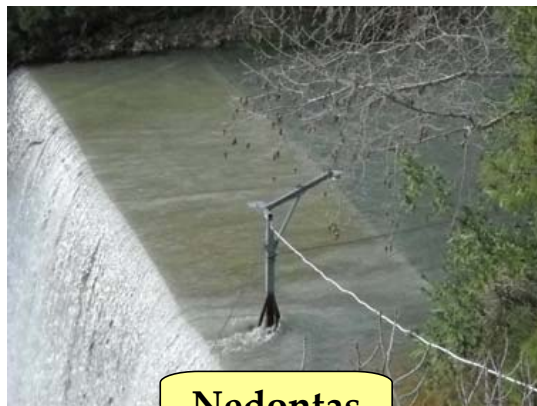
Nedontas: heterogeneity of soil permeability, permanent flow for 9-10 months, infiltration losses, outflow to urban area (Kalamata)



Lousios: high altitude, permanent runoff, significant contribution of baseflow (produced by an extended karst system), snowmelt

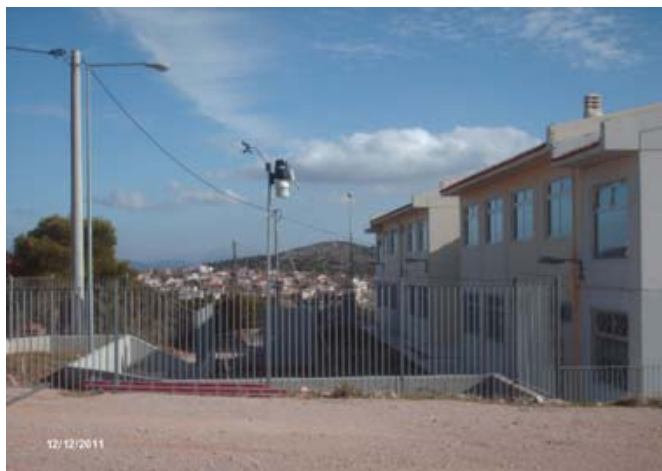
5. Monitoring infrastructure: flow stations

- For the installation of hydrometric stations, we took care to find cross-sections with stable geometry (e.g. bridges).
- When possible, we used existing manmade drops in the streambed that act as hydraulic controls, thus facilitating the indirect determination of discharge from stage measurements.
- All but one stations measure river stage, using 50-kHz ultrasonic pulses or piezometric sensors; stage measurements are always temperature-corrected.
- Particularly in Lousios, both stage and velocity are measured via an acoustic Doppler radar.
- 20-W photovoltaic panels feed the battery of each station.
- Data transfer is made via GPRS or mobile telephony.
- Data is recorded in 15-minute intervals and local storage capacity is provided for three-month data.

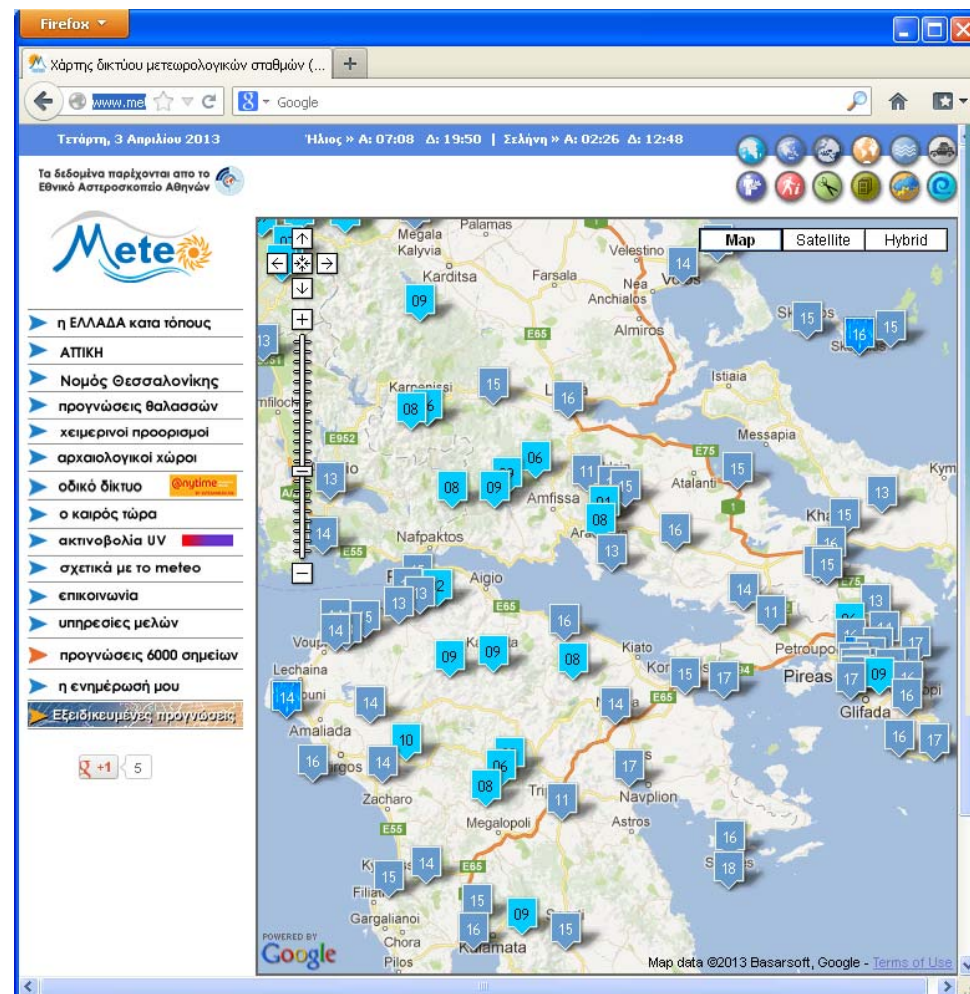


6. Monitoring infrastructure: meteorological stations

- 15 automatic meteorological stations have been installed in the context of Deucalion project, so as to provide good rainfall coverage over the pilot basins.
- All stations record precipitation, while ten of them also record air temperature, pressure, relative humidity, wind speed and wind direction (full meteorological data are essential for estimating evapotranspiration).
- These are part of a broader network of about 200 meteorological stations over Greece that are operated by volunteers, under the supervision of the National Observatory of Athens (www.meteo.gr/).
- Data are recorded in 10-minute intervals and are also logged locally for 17 days.



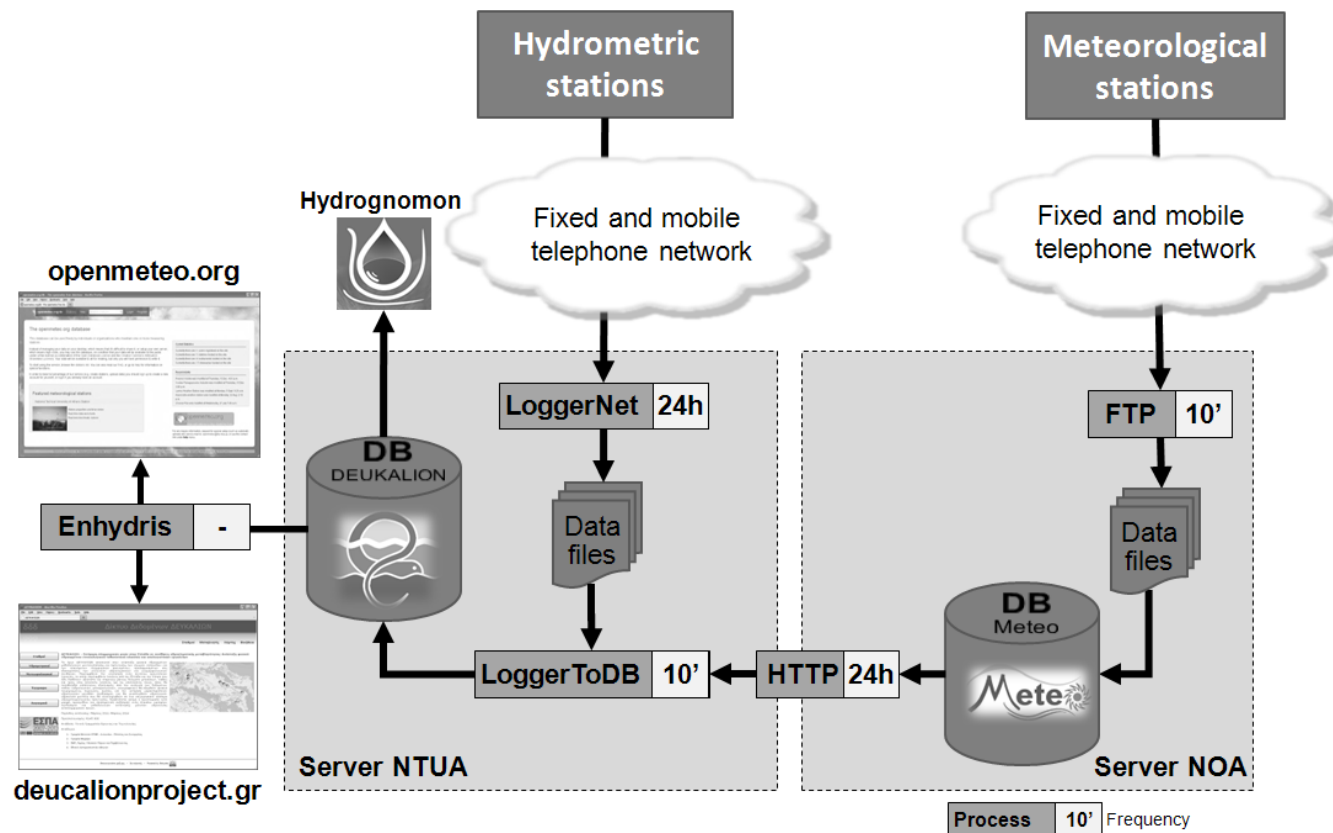
Meteorological station at Vilia (upper Sarantapotamos basin)



Web page of NOA, indicating the current air temperature values at 3/4/2013 10:00 am (www.meteo.gr/)

7. Data transfer, storage, processing & visualization

- The soft component of the network comprise a web application for supervision and management of monitoring stations and other geographical entities (**ENHYDRIS**), which is supported by a time series processing tool (**HYDROGNOMON**).
- Data are typically provided in form of text files with various formats, which are next homogenized through a specific application (LoggerToDB).
- The data are published to the web site of the project (deucalionproject.gr) as well as the openmeteo.org site; the latter is an **open source** initiative, devoted to the distribution of free hydrometeorological data and software worldwide (Kozanis *et al.*, 2011).



8. The web platform (Enhydriis & Hydrognomon)

List of selected stations

List Advanced Search

Searching

Find Stations by name, description, etc.

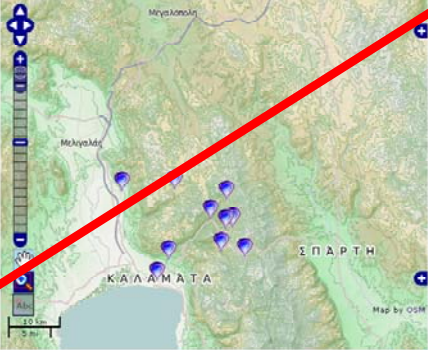
Search

☐ Display only stations with timeseries

1 Filter based search results obtained :: Back to all results ::

Station Catalogue

Filter results by map viewport



ID	Name	Water basin	Water division	Political division	Owner	Type
1343	Alagonia	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Meteorological
1340	Alagonia	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Stage - Hydrometric
1374	Arfara	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Meteorological
1354	Kalamata - Bakas Quarry	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Meteorological, Stage - Hydrometric
1367	Kalamata - Bakas Quarry	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Meteorological
1356	Kalamata - Bakas Quarry	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Meteorological, Stage - Hydrometric
1350	Nedousa	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Stage - Hydrometric
1359	Nedousa	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Meteorological
1376	Pelias	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Meteorological
1387	Taygetos	Νέδοντες	ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ	ΜΕΣΣΗΝΙΑΣ	Deukalion	Meteorological

Station details

Station Details

ID 1354

Name Kalamata - Bakas Quarry

Short Name

Remarks

Water Basin Νέδοντες

Water Division ΔΥΤΙΚΗ ΠΕΛΟΠΟΝΝΗΣΟΣ

Political Division ΜΕΣΣΗΝΙΑΣ

Abcissa 333413.09

Ordinate 4103167.28

SRID 2100

Approximate False

Altitude 75.00

ASRID None

Owner Deukalion

Type Meteorological, Stage - Hydrometric

Is Active True

Is Automatic True

Start Date 2011/12/17

End Date

Creator andreas


Overseers

Station (Genity) No data available

Alternative Codes

Station (Genity) Files No data available

Station (Genity) Generic data No data available



ID	Date	Type	User	Report
590	2013/03/05	Station malfunction	deucalion	The rainfall sensor didn't work from 2012-12-18 00:00 to 2013-03-05 09:00 EET.
597	2012/03/14	Repair/maintenance	deucalion	

Instruments No data available

ID	Name	Variable	Time step	Unit Of Measurement	Remarks	Instrument	Start Date	End Date
9210	Signal quality	Signal quality SR50A	Quarter - 15 minute(s)		Values between 152 and 210 indicate reliable measurements; between 210 and 300, reduced power; over 300, high uncertainty; zero, inability to measure, e.g. because of the target being too close to the sensor.	None	2012/03/14 10:00	2013/03/09 19:45
9213	Battery voltage	Battery voltage	Quarter - 15 minute(s)	V		None	2012/03/14 10:00	2013/03/09 19:45
9212	Rainfall	Rainfall	Quarter - 15 minute(s)	mm		None	2011/12/17 11:15	2013/03/09 19:45
9211	Air temperature	Temperature	Quarter - 15 minute(s)	°C		None	2011/12/17 11:15	2013/03/09 19:45
9209	Raw distance	Stage	Quarter - 15 minute(s)	m	Raw distance from sensor to water surface.	None	2012/03/14 10:00	2013/03/09 19:45
9157	Stage	Stage	Quarter - 15 minute(s)	m	Derived from the formula $L = D - R \cdot \sqrt{T/273.15}$, where D is the distance of the sensor from the bed, R the raw measurement of sensor distance from the surface, and T the absolute temperature. D was 1.588m until 2012-03-14 17:50, when it was changed to 1.595m.	None	2011/12/17 11:15	2013/03/09 19:45

Station "Kalamata - Bakas Quarry", Copyright (c) 2011, National Observatory of Athens.

Timeseries Details

Download Timeseries in plain text from here

ID 9157

Related Station Kalamata - Bakas Quarry

Name Στάθμη Νέδοντα στον ΑΥΣ Καλαμάτας

Variable Stage

Unit Of Measurement m

Precision 3

Time Zone EET (UTC+0200)

Remarks Derived from the formula $L = D - R \cdot \sqrt{T/273.15}$, where D is the distance of the sensor from the bed, R the raw measurement of sensor distance from the surface, and T the absolute temperature. D was 1.588m until 2012-03-14 17:50, when it was changed to 1.595m.

Instrument None

Start Date 2011/12/17 11:15

End Date 2013/03/09 19:45

Time stamps properties

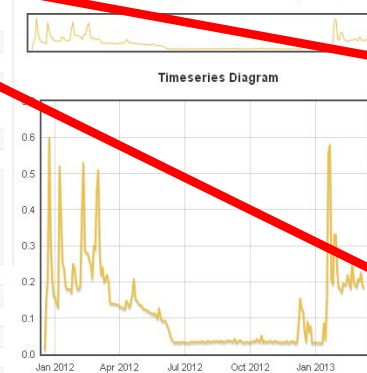
Time scale Quarter - 15 minute(s)

Time stamps regularity Time step is strict

Time stamps nominal offset 0 minutes, 0 months

Time stamps reference Instantaneous values

Actual offset of reference 0 minutes, 0 months



Timeseries details

Station "Kalamata - Bakas Quarry", Copyright (c) 2011, National Observatory of Athens.

Hydrognomon

File Edit View Series Hydrology Help

Extremes evaluation...

Double mass curve...

Evapotranspiration...

Hydrometry...

Curves and interpolations...

Regression and infilling...

Spatial integration - surface rainfall...

Zygos - Basin simulation...

Pythia - Statistical analysis...

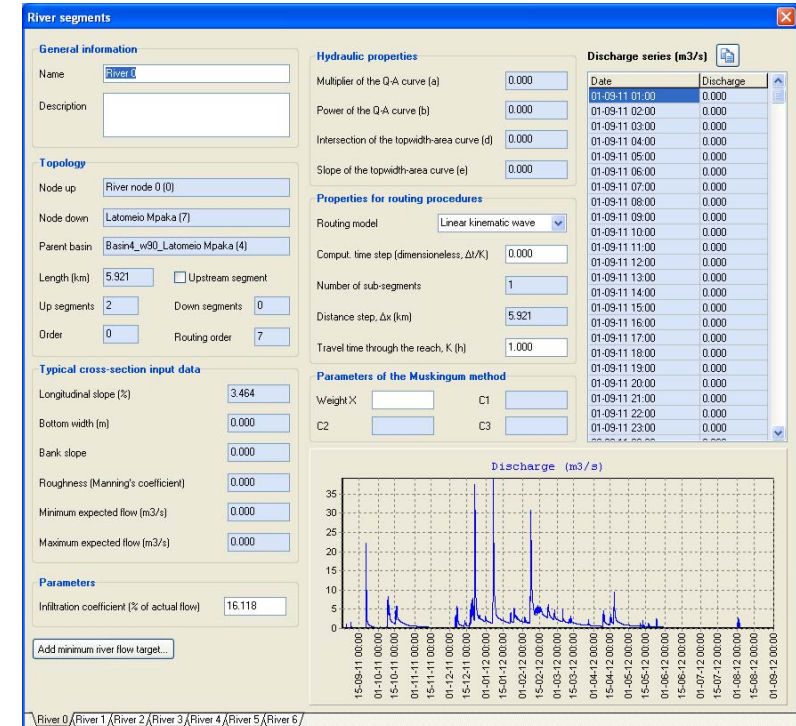
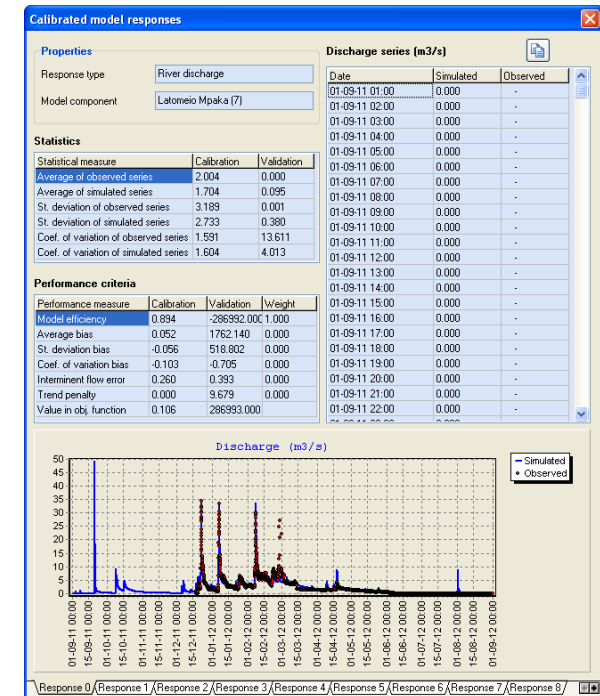
Ombros - IDF curves...

Time series regression and infilling of missing values

Timeseries processing (Hydrognomon)

9. Sample flood modeling application

- A key objective of Deucalion project is the development of **continuous simulation models** for the representation of flood flows across hydrographic networks of any complexity.
- Continuous simulation is essential for properly interpreting **flood risk** as joint probabilities of all hydrological variables that interrelate in runoff generation (rainfall, soil moisture).
- We used as basis the **HYDROGEIOS** software, initially oriented to water management problems in modified river basins, for which monthly simulations are adequate (Efstratiadis *et al.*, 2008; Nalbantis *et al.*, 2011).
- The software was enhanced and improved to also support **daily and hourly time steps**, thus being suitable for the representation of flood processes.
- The new version of HYDROGEIOS was evaluated in the **river basin of Nedontas**, and its performance was contrasted to the well-known HEC-HMS software (Zogakis, 2013).
- The simulation period for model testing was a full hydrological year (1/9/2011 to 31/8/2012), for which we aimed to reproduce the observed hourly flows at the **three measuring stations** (Nedontas outlet, Alagonia, Karveliotis).



10. The HYDROGEIOS modeling system

- **Rainfall-runoff module**

- Semi-distributed schematization of the surface hydrological system (river network, sub-basins);
- Conceptualization through interconnected tanks that represent the key hydrological processes on the ground and the unsaturated zone, using seven parameters;
- Model parameters are considered homogeneous within Hydrological Response Units (HRUs), defined by the classification of properties such as permeability, land cover, terrain slope, etc.;
- Model inputs: precipitation & potential evapotranspiration (PET) data, varying per sub-basin;
- Model outputs: actual evapotranspiration, percolation, runoff.

- **Groundwater module**

- Finite-volume approach (Rozos and Koutsoyiannis, 2006), aquifer discretization to few polygonal cells of flexible shape, Darcian representation of flow field;
- Stress data: percolation, infiltration, pumping;
- Model parameters: conductivities, specific yield;
- Model outputs: groundwater level, baseflow (through springs), underground losses.

- **Water allocation & management module**

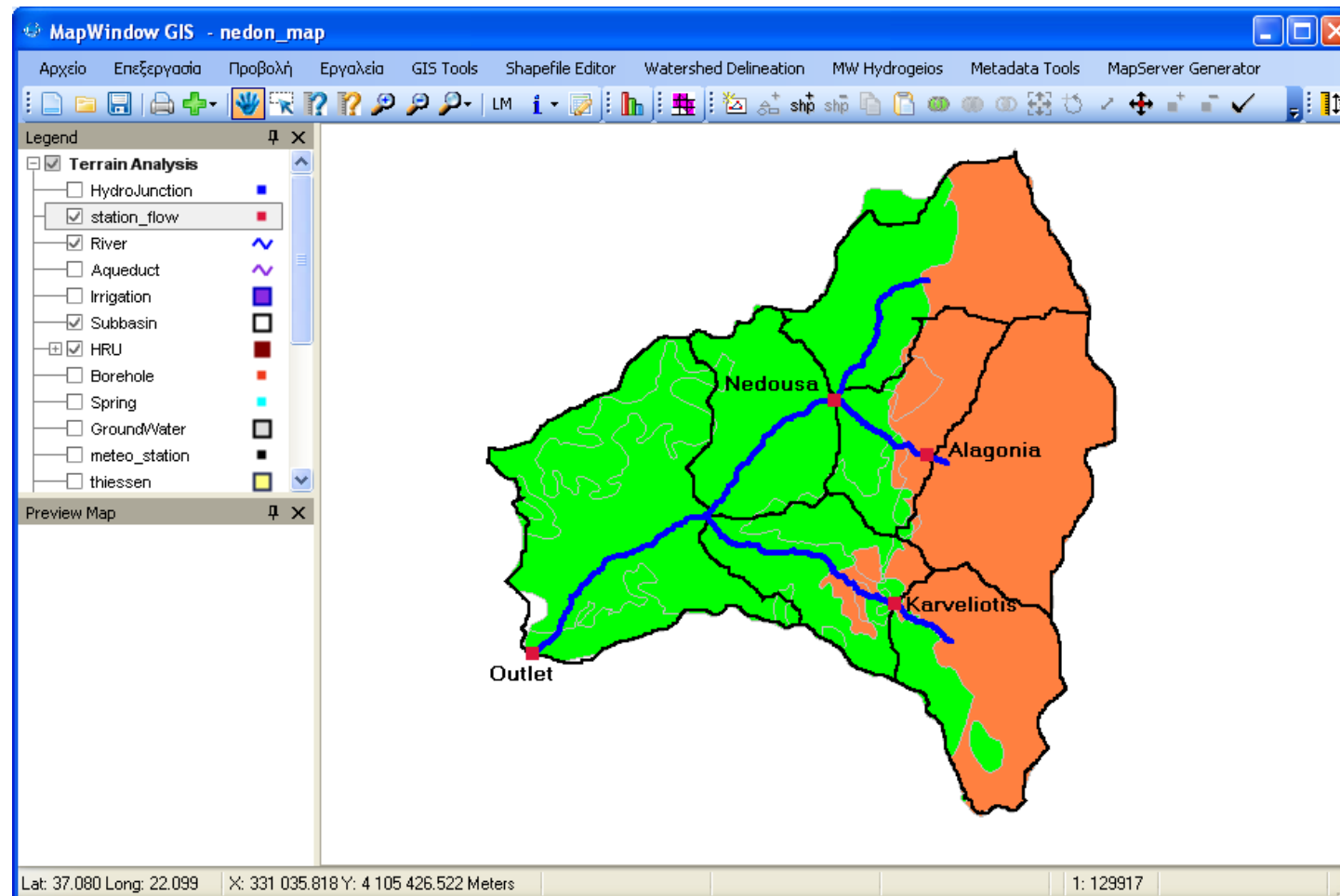
- Network-type representation of water uses and main hydraulic structures;
- Estimation of unknown flows and abstractions through linear optimization.

- **Routing module**

- In-basin routing of hydrographs through a linear reservoir approach;
- Propagation of hourly hydrographs along the river network through a kinematic-wave or a Muskingum diffusive-wave model, for steep and mild slopes, respectively (Koussis, 2009, 2010).

11. Geographical inputs (MapWindow environment)

- 7 sub-basins, 5 river nodes (hydrometric stations and junctions);
- 2 HRUs, assuming two permeability classes;
- one groundwater cell beneath each sub-basin;
- 4 springs, implementing the generation of baseflow;
- one dummy cell, accounting for underground losses.



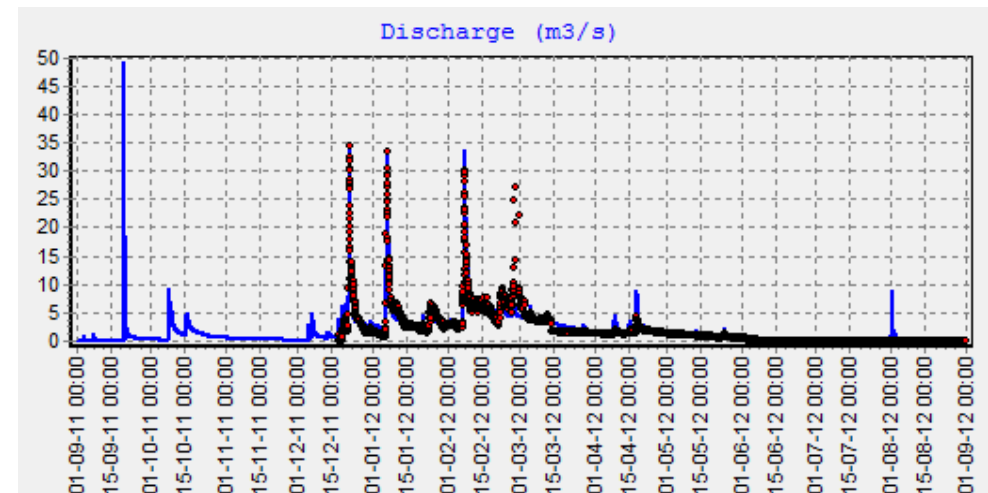
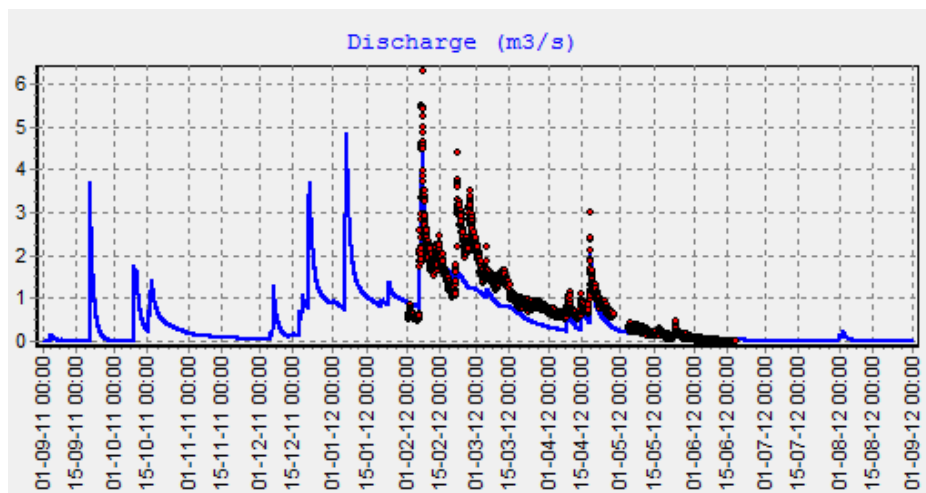
12. Input hydro-meteorological data

- **Rainfall time series**
 - Aggregation of 10-minute data records to hourly intervals;
 - Filling of missing values through linear regression analysis;
 - Areal integration through the Thiessen polygon method;
 - Adjustment to mean elevation of each sub-basin, assuming an annual rain slope of 0.75 mm/m.
- **Potential evapotranspiration (PET) time series**
 - Aggregation of 10-minute temperature records to daily and monthly intervals;
 - Use of a simplified expression of the Penman-Monteith formula (Tegos *et al.*, 2013) for the estimation of monthly PET, on the basis of mean monthly temperature, extraterrestrial solar radiation and regional parameters that have been calibrated against local meteorological data;
 - Empirical disaggregation of monthly to daily PET, on the basis of daily temperature;
 - Elementary estimation of hourly PET.
- **Discharge time series**
 - Pre-processing of raw stage data (removal of negative values, adjustment to an offset stage);
 - Establishment of theoretical rating curves (i.e. stage-discharge relationships) to the three cross-sections, assumed that the measured stage corresponds to the critical flow depth;
 - Further analysis, based on the FLOW3D software, to better represent the high flows;
 - Calculation of instantaneous flows at 15-min intervals and estimation of mean hourly discharge through aggregation.

For the processing of raw hydro-meteorological data and the preparation of the input time series, we used the HYDROGNOMON software.

13. Model calibration

- Formulation of an weighted objective function, comprising two criteria:
 - Coefficients of efficiency at the three measuring stations (primal criterion);
 - Empirical measures (trend penalties), assigned to all cells, which ensures a “reasonable” representation of groundwater dynamics.
- Hybrid multicriteria calibration:
 - Automatic optimization of small sets of model parameters, employing the evolutionary annealing-simple method (Efstratiadis and Koutsoyiannis, 2002);
 - Manual guidance of search towards promising areas of the search space, taking advantage of hydrological experience;
 - Detection of a compromise parameter set, which exhibits satisfactory predictive capacity at all measured sites.
- Key results, in terms of efficiency: Alagonia = 0.77; Karveliotis = 0.59; outlet = 0.95



Simulated vs. observed hourly flows at Alagonia (left) and the outlet of Nedontas basin (right)

14. Conclusions & proposals for further research

- After two years of development and pilot testing, most of the system components (hard: monitoring network; soft: applications and models) are fully **operational**.
- The monitoring network can (and should be) expanded, to cover more basins, particularly those lying in potentially hazardous areas.
- The soft component, which has been implemented as **open-source** software, comprises general-purpose tools, which are applicable to a wide range of water resource problems.
- ENHYDRIS & HYDROGNOMON can effectively support the **supervision and management of hydrometeorological networks**, without restrictions to the number of users and the extent of data.
- The upgraded version of HYDROGEIOS, with parameters properly fitted to local data, ensures both **physical consistency** and **parsimony** in the representation of the hydrological processes, at fine time intervals.
- In next research steps, HYDROGEIOS will be integrated with other modules, i.e.:
 - a **rainfall generator**, providing synthetic rainfall time series to the hydrological model, in order to run in stochastic simulation mode, for the statistically consistent evaluation of flood risk within hydrological design studies;
 - a **hydraulic simulation** tool, to be employed within flood inundation studies;
 - a **numerical weather prediction** system, to evaluate the basin's response against ensembles of short-term rainfall data.

This presentation is available at <http://itia.ntua.gr/en/docinfo/1329/>

References

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