FREEWAT
Free and Open Source Software Tools for Water Resource Management
EU HORIZON 2020 Project

European Commission

EIP Water Online Market Place
Matchmaking for water Innovation
MAR Solutions - Managed Aquifer Recharge Strategies and Actions (AG128)

The Horizon 2020 FREEWAT project: FREE and open source software tools for WATer resource management

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idaea CSIC GHS UPC

www.freewat.eu

FREEWAT is an ICT project for improving Water Resource Management (WRM)

MAIN EXPECTED RESULT

Open source and public domain GIS integrated modelling platform for promoting WRM by simplifying and strengthening the application of WFD, GWD and other water related Directives.

FREEWAT expected main impact →

help producing scientifically and technically sounding decision and policy making based on:

- data and innovative data analysis tools and
- including participatory approach not only in the final stage of discussion but also during the phase of scenario generation.

FREEWAT
Concept and Motivations/1

1. **ICT tools** to boost the application of the WFD and water related Directives;

2. **free** and open source tools, numerically based, GIS integrated to perform spatial and temporal analysis on water quantity and quality issues; use effectively data provided by the extensive monitoring required by the WFD;

3. **training technical staff** at authorities and private companies on the use of state-of-the-art innovative software for water management; capacity building within the EU water sector.

FREEWAT
Concept and Motivations/2

4. readily available ICT tools to analyse **conjunctive use** of surface- and ground-water, the **impacts of land use and urban sprawling** and of **climate change** on water resource;

5. including **participatory approach** earlier than only result discussion;

6. **supporting scientific research** results to foster their real scale application and uptake by policy makers and water authorities.

Open source characteristics of the project→

initiative "*ad includendum*" - further research institutions, private developers etc. may contribute to the project development.

FREEWAT objectives

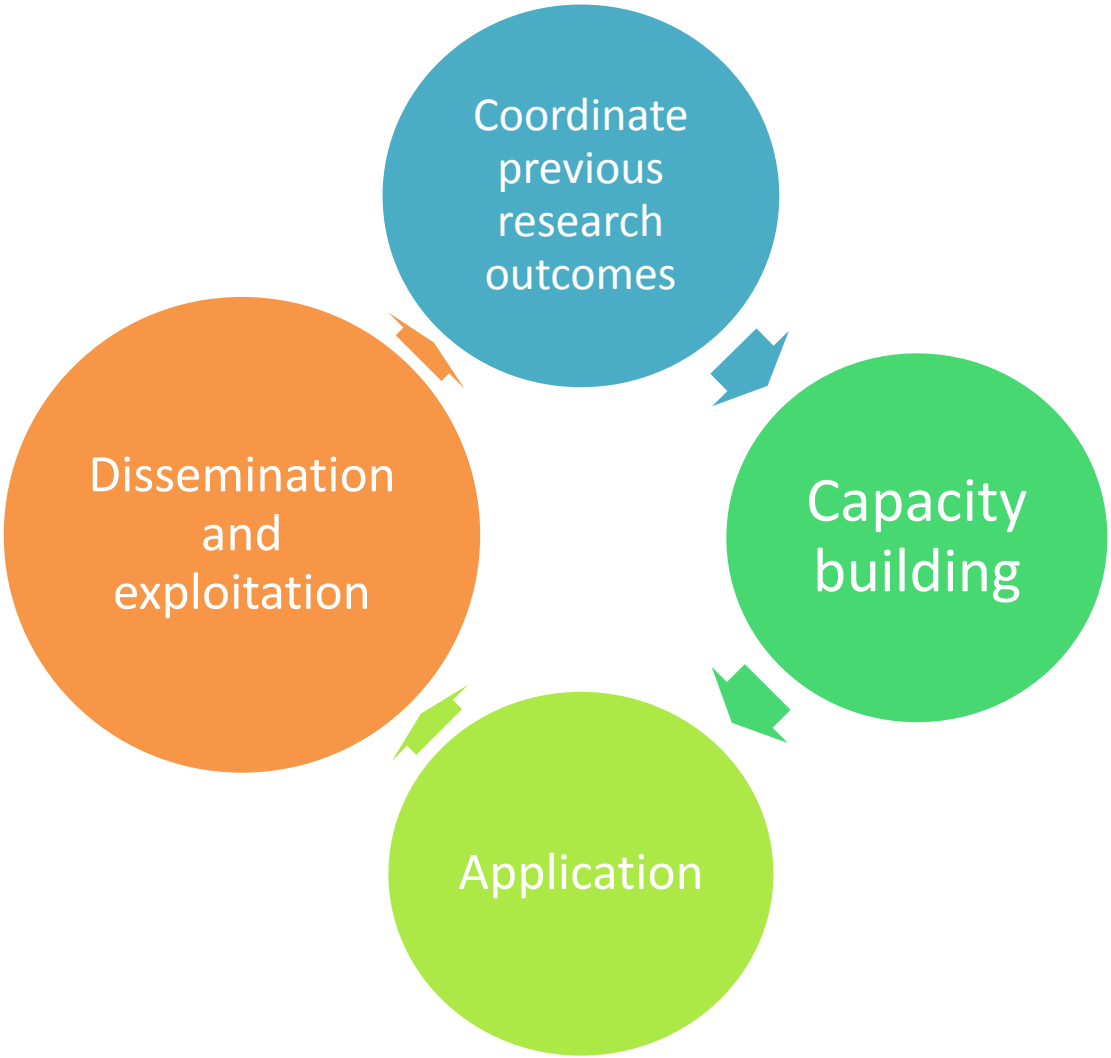
- to **coordinate previous EU and national funded research** to integrate existing software modules for water management in a single environment into the GIS based FREEWAT;

- to support FREEWAT application in an innovative participatory approach **gathering technical staff and relevant stakeholders** (policy and decision makers) in designing scenarios for proper application of water policies.

FREEWAT Consortium

DURATION: 30 months – started April 1st 2015 – to September 2017

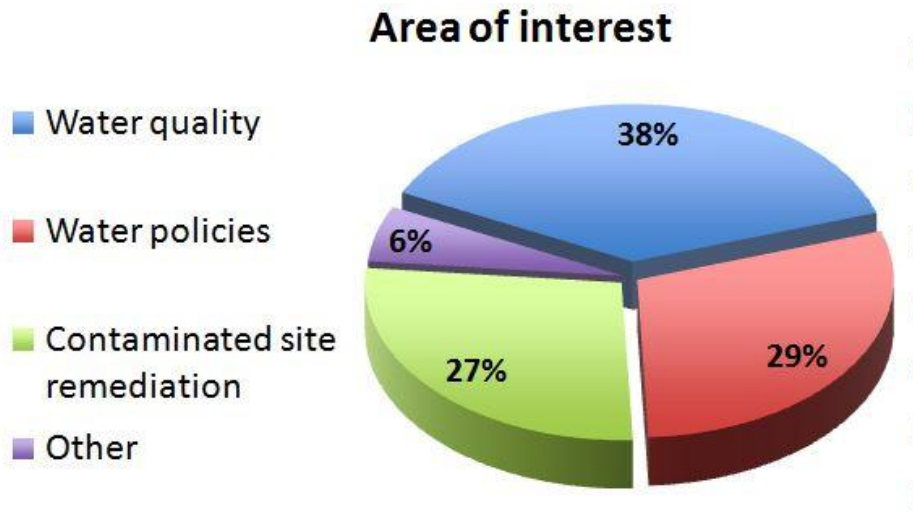
FREEWAT circular economy

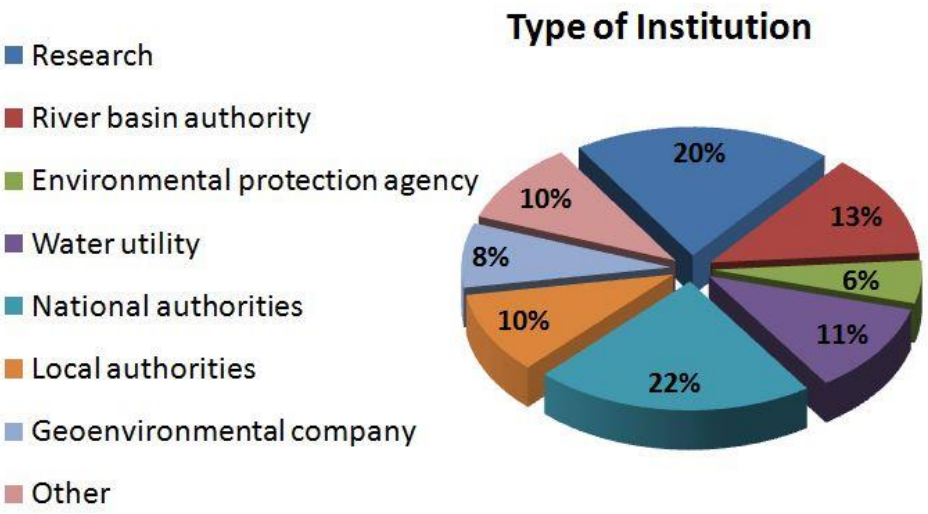


FREEWAT CAPACITY BUILDING

- Large stakeholders involvement (more than 200 stakes going to be involved)
- Web social and professional networks

(linkedin group launche 272 followers)

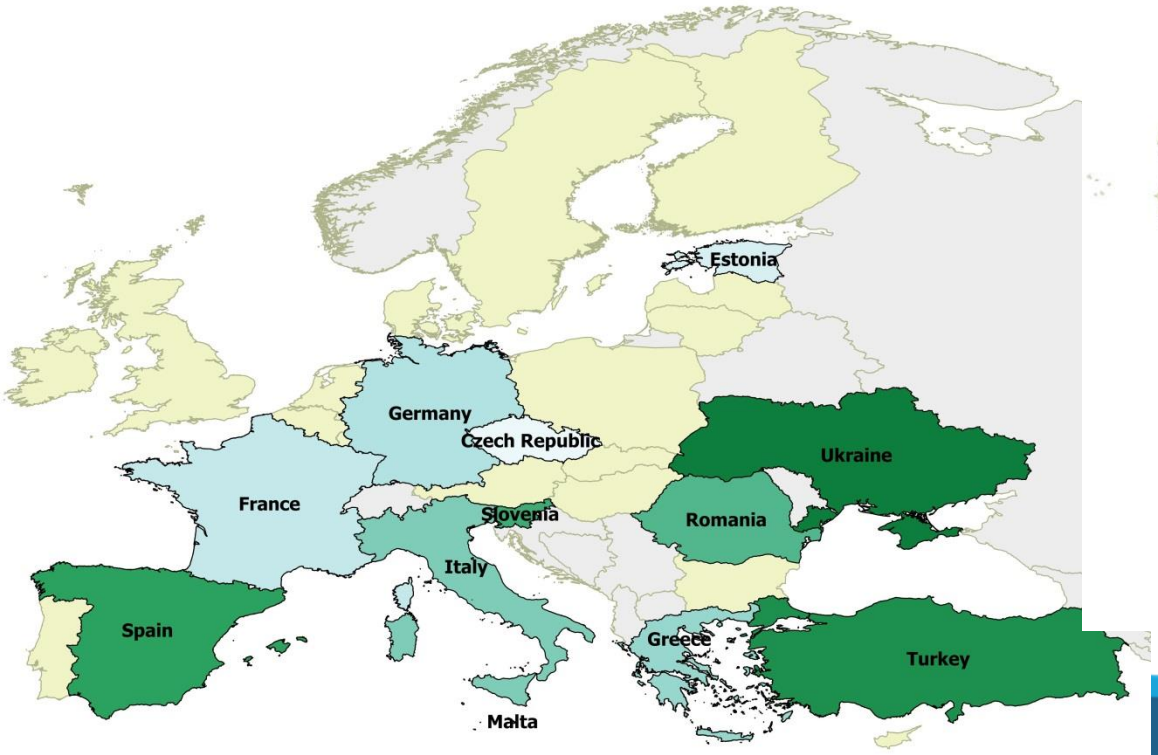




FREEWAT case studies

14 case studies:

- 8 for the application of WFD, GWD and others (EU countries) plus 1 case study in Switzerland (SUPSI, collaborating Institute)
- 5 devoted to rural water management: 2 EUs, Turkey, Ukraine, and Africa (through UNESCO involvement)



And now we are ready to move to the modelling platform!

- What comes from previously funded efforts?
- What new will be integrated into the FREEWAT platform within the FREEWAT project?
- **Which other tools would you like to see there?**

→ extremely useful and challenging answers about this from a questionnaire sent out to stakeholders all over Europe!!!

Which EU and national previous efforts are taken into account in FREEWAT?

- **SID&GRID** (Regione Toscana): Surface water and groundwater flow and unsaturated zone processes in gvSIG GIS (*superseeded*)
- **MARSOL** (EU, FP7): solute transport in groundwater
- **QUIMET** (Catalan Water Agency): GIS based hydrogeochemical analysis tools
- **REGIONE TOSCANA**: porting of SID&GRID into QGIS
- … plus not only EU-made codes

And potentially:

- **NITRATOS** (EU, LIFE)
- **FEDER12** (France): 3D databases, namely **PostGIS 3D**, to be able to store and manipulate 3D objects and 3D meshes
- …

Unione europea
Fondo sociale europeo

REGIONE TOSCANA

POR FSE 2007-2013
Fondo Sociale Europeo
Programma Operativo
Regione Toscana

Ministero del Lavoro, della Salute e delle Politiche Sociali
Direzione Generale per le Politiche per l'Orientamento e la Formazione

SID&GRID

Hydroinformatics and simulation for water resource management

EU POR FSE 2007-2013

April 2010 --- March 2013

Partners:

Dep. of Matematica, Uni. of Firenze

Land Lab, Scuola Superiore S.Anna, Pisa

CNR-ISTI, KDD Lab, Pisa

Ingegnerie Toscane S.r.l.

Autorità di Bacino del Fiume Serchio Lucca

H_2O Ingegneria S.r.l., Pisa

Studiorum Universitas Florentina

ISTITUTO DI SCIENZA E TECNOLOGIE DELL'INFORMAZIONE "A. FAEDO"

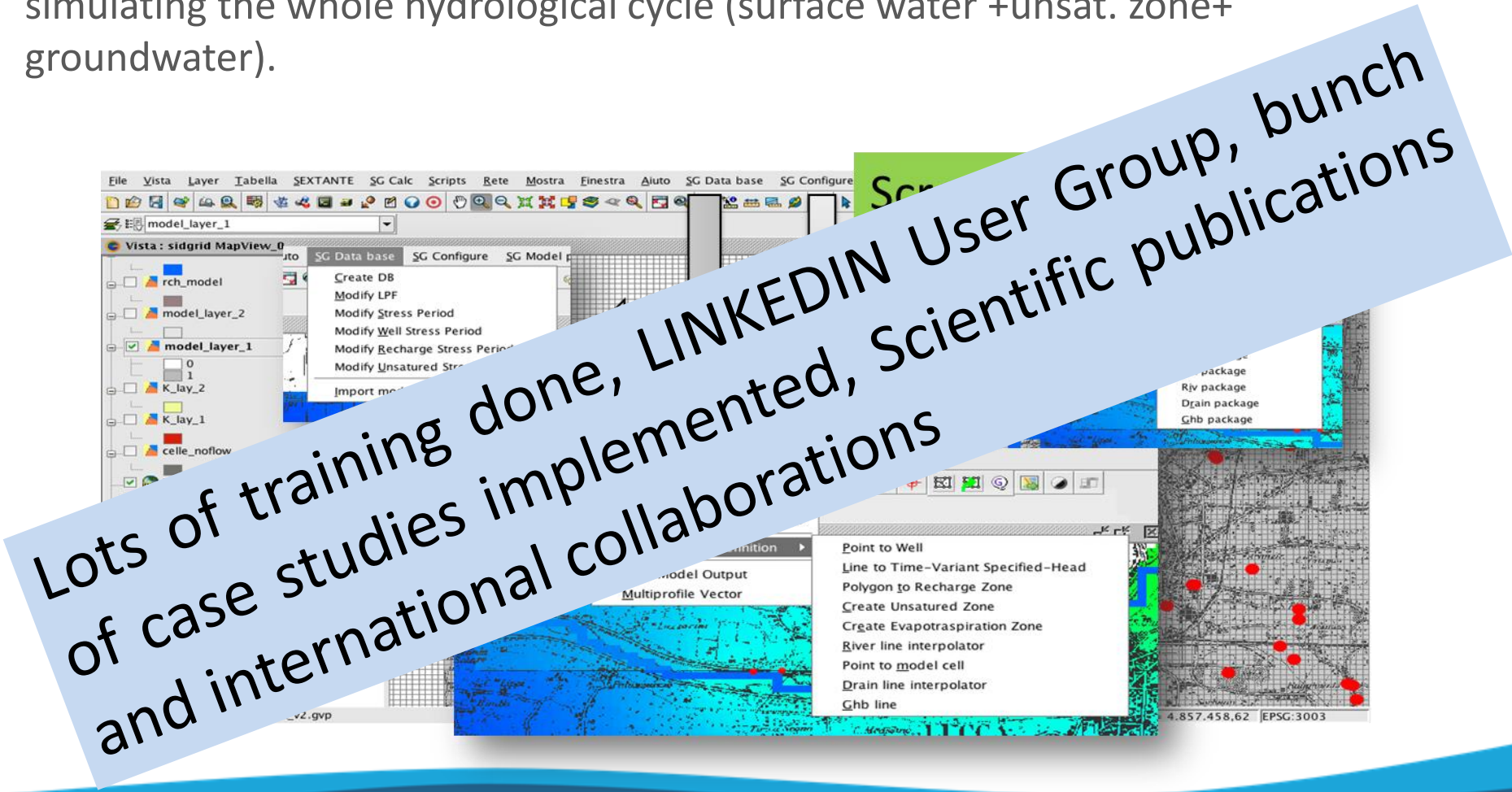
santAnna school of advanced studies

INGEGNERIE TOSCANE

Autorità di Bacino
BACINO PILOTA DEL FIUME SERCHIO

SID&GRID?

Open source and public domain GIS integrated 3D hydrological model for simulating the whole hydrological cycle (surface water +unsat. zone+ groundwater).



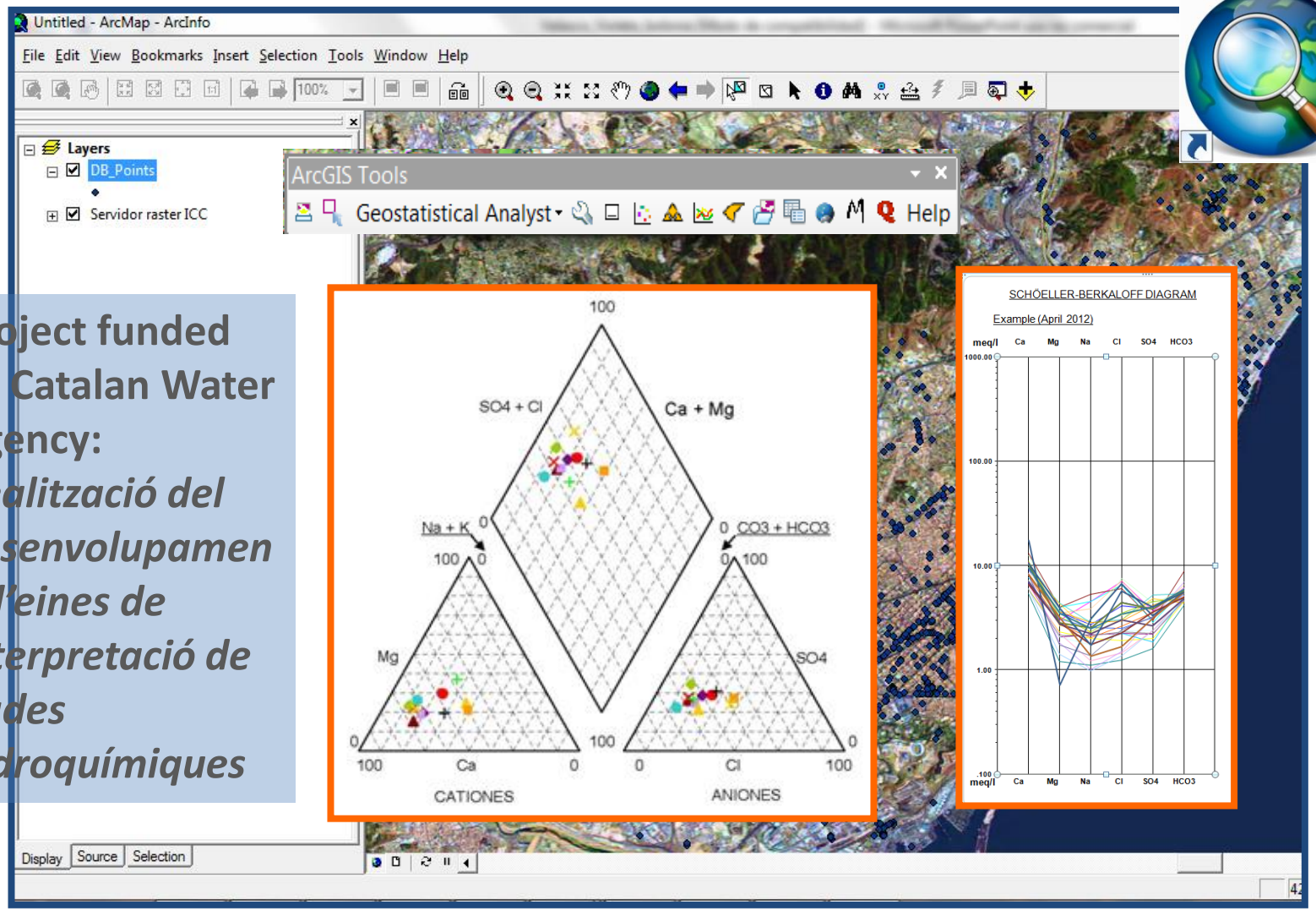
From SID&GRID to FREEWAT

Successful SID&GRID development suggested to boost its usage and to improve its capabilities!!!

Road map:

- Including capability for heat and solute transport in aquifer(s) (i.e.: model contamination plumes, well field protection areas, seawater intrusion, geothermal plants (very low/low enthalpy), managed aquifer recharge plant)
  - ➢ In FP7 MARSOL Project
- Extending its usage and related community: larger community of users and developers, a more rich set of GIS plug-in to be used in synergy with models
  - ➢ Regione Toscana co-financed the porting of the system to QGIS
- Including many other capabilities, especially linked with water management issues
  - ➢ H2020 FREEWAT Project

QUIMET?



Project funded by Catalan Water Agency: ***Realització del desenvolupament d'eines de interpretació de dades hidroquímiques***

FREWAT key components

- Qgis as GIS desktop interface
- SpatiaLite (spatial extension of SQLite) as GeoDB Management System
- FloPy as reference Python library to connect Qgis with hydrological codes

FREEWAT NEW MODULES → development already ongoing!

1. **Solute transport** in the **unsaturated** zone (TEA Sistemi)
2. **Water management** and planning (TEA Sistemi, Pisa)
3. **Observations Analysis Tools** (SUPSI, Switzerland, coll. Institute)
4. **Lake package** (SUPSI, Switzerland, collaborating Institute)
5. **Calibration**, uncertainty & sensitivity analysis (TU Darmstadt)
6. Management of water in **agriculture** (SSSA, Pisa)
7. Tools for dealing with **groundwater quality** issues (IDAEA-CSIC, Barcelona)
8. Tools for the analysis, **interpretation and visualization of hydrogeological** data (IDAEA-CSIC, Barcelona)

SOLUTE TRANSPORT IN UNSATURATED ZONE

Iacopo Borsi
TEA Sistemi, Pisa

MODELS REVIEW AND SELECTION

Several codes are available to address the problem of solute transport in vadose zone.

Our criteria to select the “best code” for FREEWAT:

- Free and open source license (compulsory!!)
- Coupling with a MODFLOW/MT3DMS [groundwater flow/transport model]: this part is crucial. An easy coupling method is a priority!

SOLUTE TRANSPORT IN UNSATURATED ZONE (ctd.)

MODELS REVIEW AND SELECTION

Selection phase leads to the following options

Best solution: UZF-MT3DMS

- It is a recent development of MODFLOW: basically, it extends the use of MT3DMS to the unsaturated zone, where water flow is calculated by UFZ package (Morway et al., GROUNDWATER, Vol. 51, no. 2 , 2013)
- Strength: coupling with MODFLOW is done!
- Weakness: not officially released yet (latest check: August 2015)

Other good solutions (if UZF-MT3DMS will not be released on time, w.r.t. FREEWAT timeline):

- SWAP
- HYDRUS 1D

MODULE for WATER MANAGEMENT 2

Iacopo Borsi
TEA Sistemi, Pisa

MODELS REVIEW AND SELECTION

Limited number of available options.

→ Two most likely options are:

GWM - Groundwater Management Process (MODFLOW)

- It uses a response–matrix approach to solve several types of linear, nonlinear, and mixed–binary linear ground–water management formulations. Each management formulation consists of a set of decision variables, an objective function, and a set of constraints.
- Strength: coupling with MODFLOW is done!
- Weakness: GWM focus on groundwater problems, while in FREEWAT we would address a larger part of the water management issue. However, it seems that some “surface-oriented” problems can be modelled as well (aquifer managed recharge, rivers depletion, etc.)

MODULE for WATER MANAGEMENT 2

MODELS REVIEW AND SELECTION

WEAP (-derived) code (Stockholm Environment Institute)

- WEAP (Water Evaluation And Planning) takes an integrated approach to water resources planning (full integration of supply, demand, water quality and ecological considerations)
- Strength:
    - coupling with MODFLOW is possible.
    - A large variety of water management problem are addressed
- Weakness: **not (really) free.** Thus, a re-code is necessary, taking WEAP as example…. Hard work to do! (Maybe) such a task is not compatible with FREEWAT timeline and resources.

Observation Analysis Tool: OAT

Massimiliano Cannata

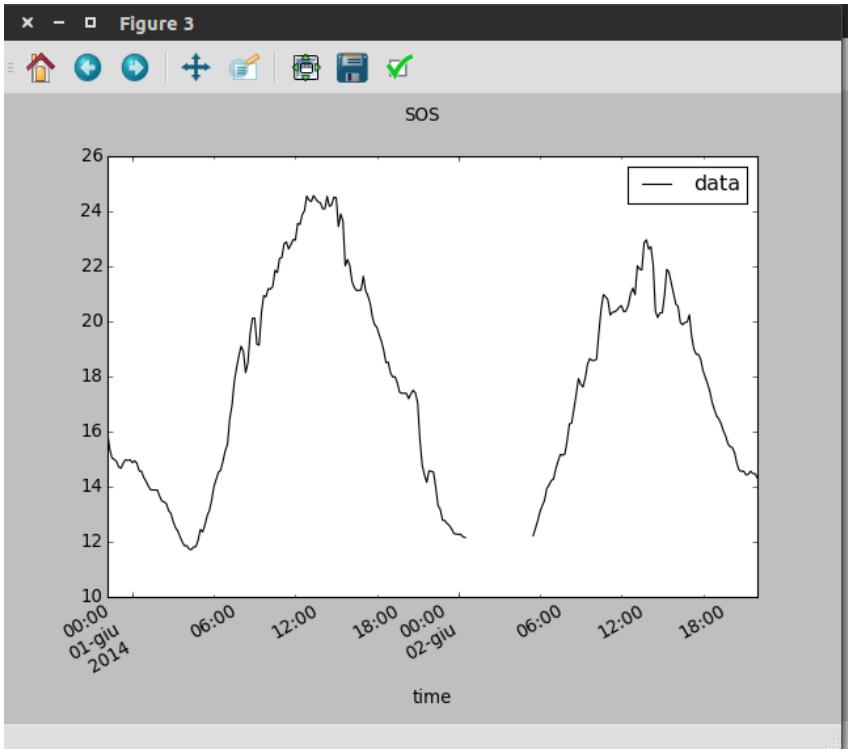
SUPSI, Switzerland, collaborating Institute

Time-series data processing

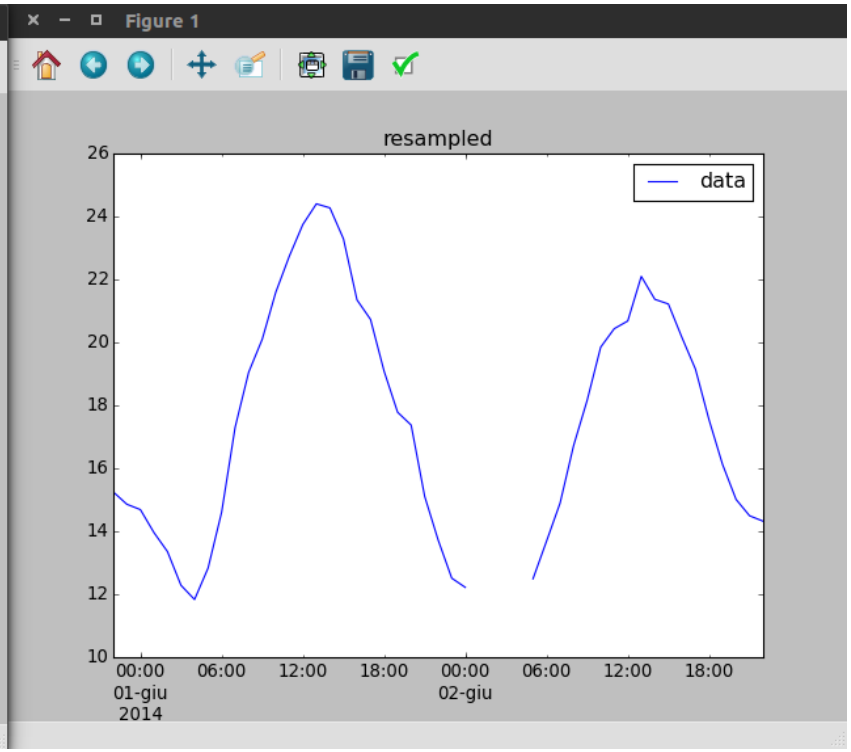
1. help in the **preparation of model input** data and in the statistical analysis of observations and model results.
2. allow to better focus the model calibration to intended use: simulate extreme events, simulate daily flow volume, etc.
3. Similarly to the TSPROC utility of PEST → enable **analysis of raw data** (regularization, data interpolation, fitting, filling, validation and data quality assessment); decomposition or **filtering of time-series** (low, medium, high frequencies); aggregation and exceedance-time calculation, summary **statistics** and period statistics; hydrological indexes; etc.

For example plots of object:

Original 10 min



Resampled 1h



Aquifer-Lake interaction

Massimiliano Cannata
SUPSI, Switzerland, collaborating Institute

LAK package

Lake-groundwater interaction requires a code dynamically integrating groundwater, unsaturated zone and lake fluxes

This can be achieved with MODFLOW activating:

- the Lake Package (LAK7),
- the Stream Flow Package (SFR7) and
- the Unsaturated Zone Flow (UZF1) Package

LAK package

The LAK package is integrated into MODFLOW by specifying lake nodes in the model finite-difference grid, then, the lake stage is calculated relying on the computed fluxes into and out of the lake and the overall lake water balance (Hunt, 2003).

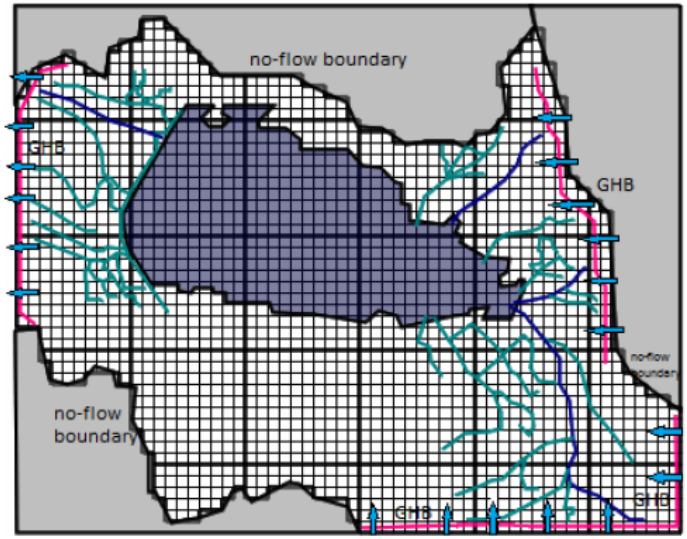


Figure 2-4 External boundary conditions; in black no-flow boundaries and in red, inflow and outflow boundaries.

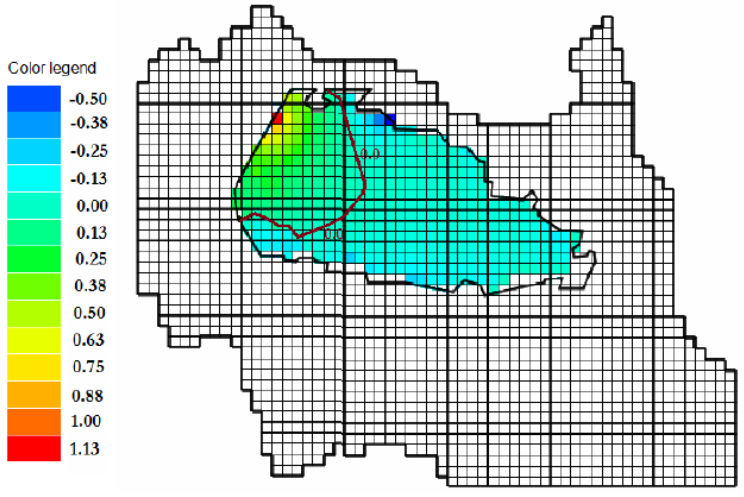


Figure 3-20 Distribution of lake seepage [mm.day^{-1}] and zero contour line.

Lake seepage (+out lake, - in lake)

Source: assessment of lake groundwater interaction: Turawa case, Poland
PhD Thesis, Arm El Zehairy, 2014

Calibration & Sensitivity Analysis Tools

Laura Foglia & Steffen Mehl
TU Darmstadt

UCODE_2014 in FREEWAT

What can it provide?

Universal tool for:

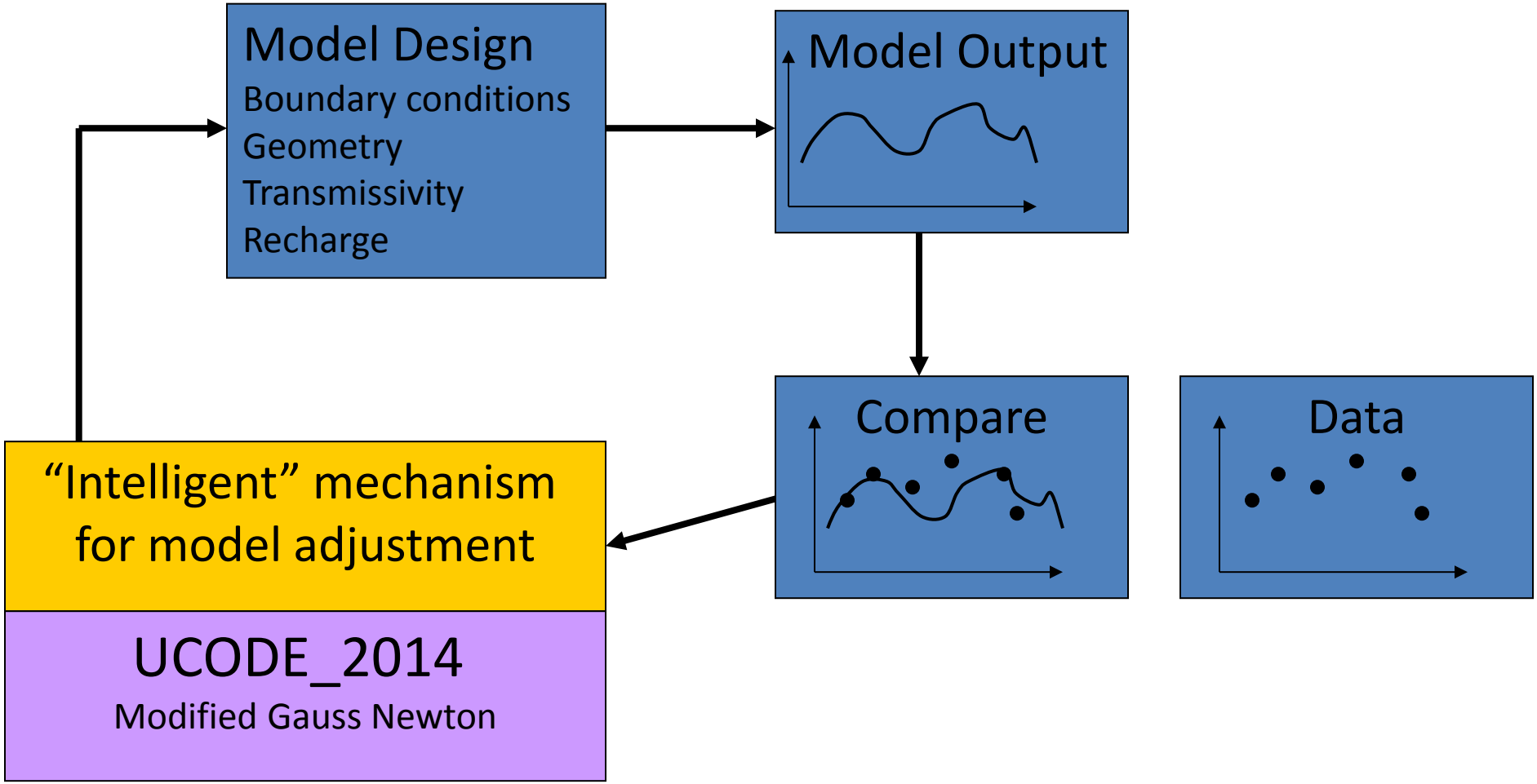
1) Sensitivity Analysis
   - How much information do observations provide?
2) Data Assessment
   - Which observations dominate?
3) Model Calibration/Parameter Estimation
   - What parameter values provide best fit to data?

Ucode_2014 Capabilities to be integrated

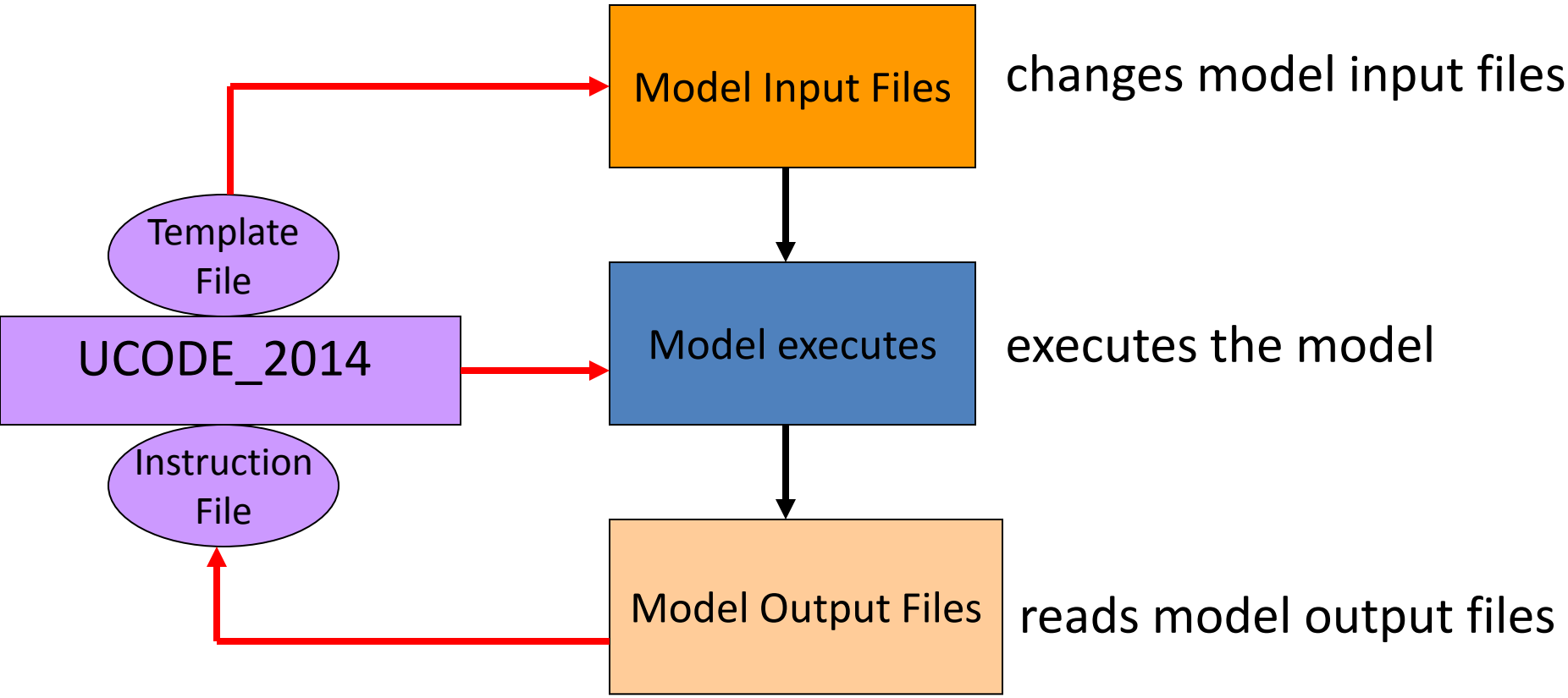
- Provide interface within Freewat for defining typical Modflow parameters (K, storage, recharge, etc.)
- Provide interface for defining typical inputs to UCODE_2014 (perturbation size, log transform, etc.)
- Post process results for typical analyses (sensitivities, model fit, etc.)

Model Calibration

Using Ucode-2014



How Ucode-2014 Works



Water management and irrigation in agriculture

Federico Triana & Rudy Rossetto

Scuola Superiore Sant'Anna, Pisa

Water management and irrigation in agriculture

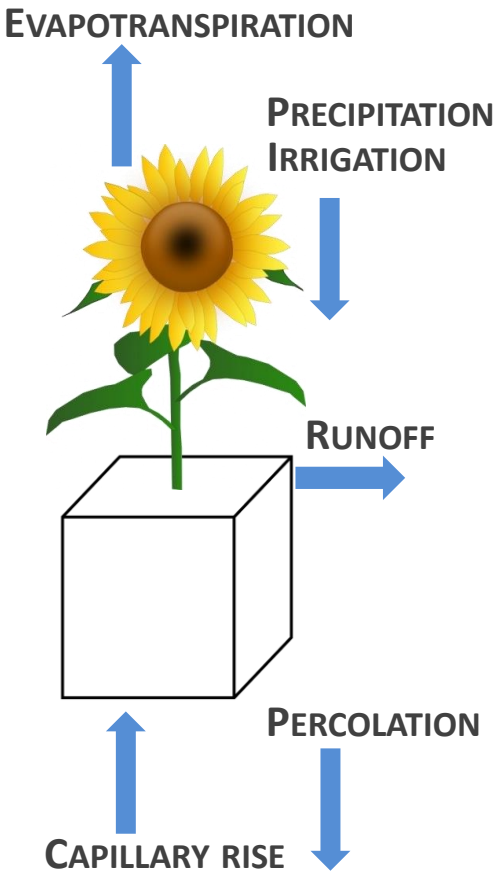
Federico Triana & Rudy Rossetto
Scuola Superiore Sant'Anna, Pisa

Widely needed feature

estimate supply-and-demand components of water flows in agriculture

Fundamental components include:

- plant water uptake
- evaporation
- precipitation
- surface-water delivery
- capillary rise from ground-water
- Groundwater pumping
- irrigation runoff
- deep percolation of excess water



Water management and irrigation in agriculture

How to dynamically integrate it as part of the simulation of surface-water and ground-water flow?

Two-sided solution:

Farm Process coupled to MODFLOW

+

Crop-Growth Module based on EPIC (crop and soil productivity simulation model)

Simulates:
water distribution and trasport (e.g. well pumpage, channels, pipes)

AND

plant-soil-atmosphere water interactions (evapotranspiration, percolation, run-off)

Water management and irrigation in agriculture

How to dynamically integrate it as part of the simulation of surface-water and ground-water flow?

Two-sided solution:

Farm Process coupled to MODFLOW

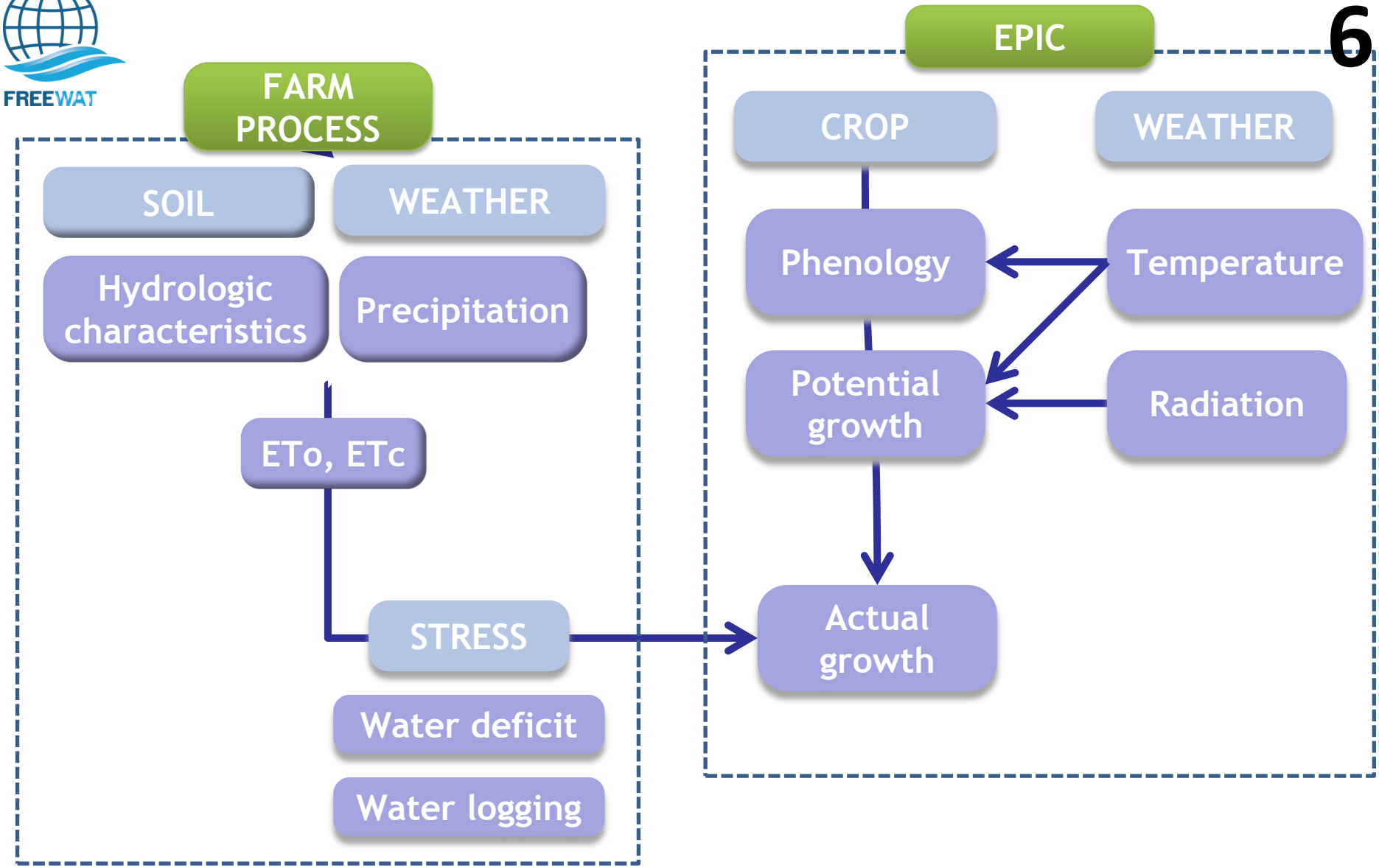
+

Crop-Growth Module based on EPIC

Simulates:
potential crop growth
(under optimal water conditions)

AND

Actual crop growth taking into account water stress (estimated by *Farm Process*)



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642224

Hydrochemical analysis tools for QGIS (AkvaGIS)

IDÆA-CSIC, Barcelona, Spain

Actual development

Completed modules:

- AkvaGIS Database and Editing
- Management of saved queries
- Measurements Selection Form
- Results Table & Chart (SAR, Piper, Schoeller Berkalof Diagram, Time Plot)

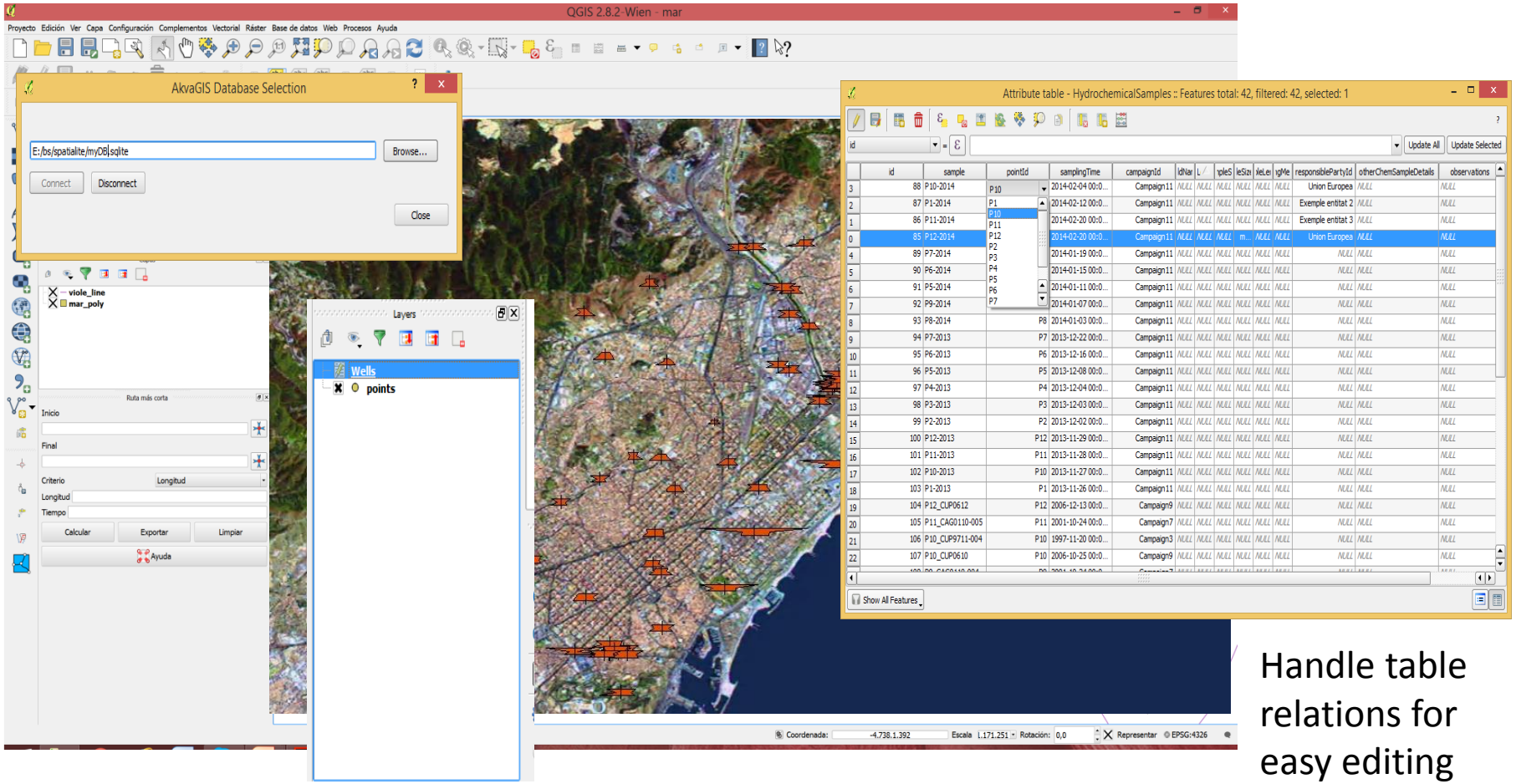
Modules in development:

- Maps (regulatory) parameters, Stiff)
- Ionic Balance Report

AkvaGIS Database and Editing

Select AkvaGIS database to use:

Use of QGIS layers to edit AkvaGIS tables with QGIS table attributes:



Handle table relations for easy editing

FREEWAT - Free and Open Source Software Tools for Water Resource Management

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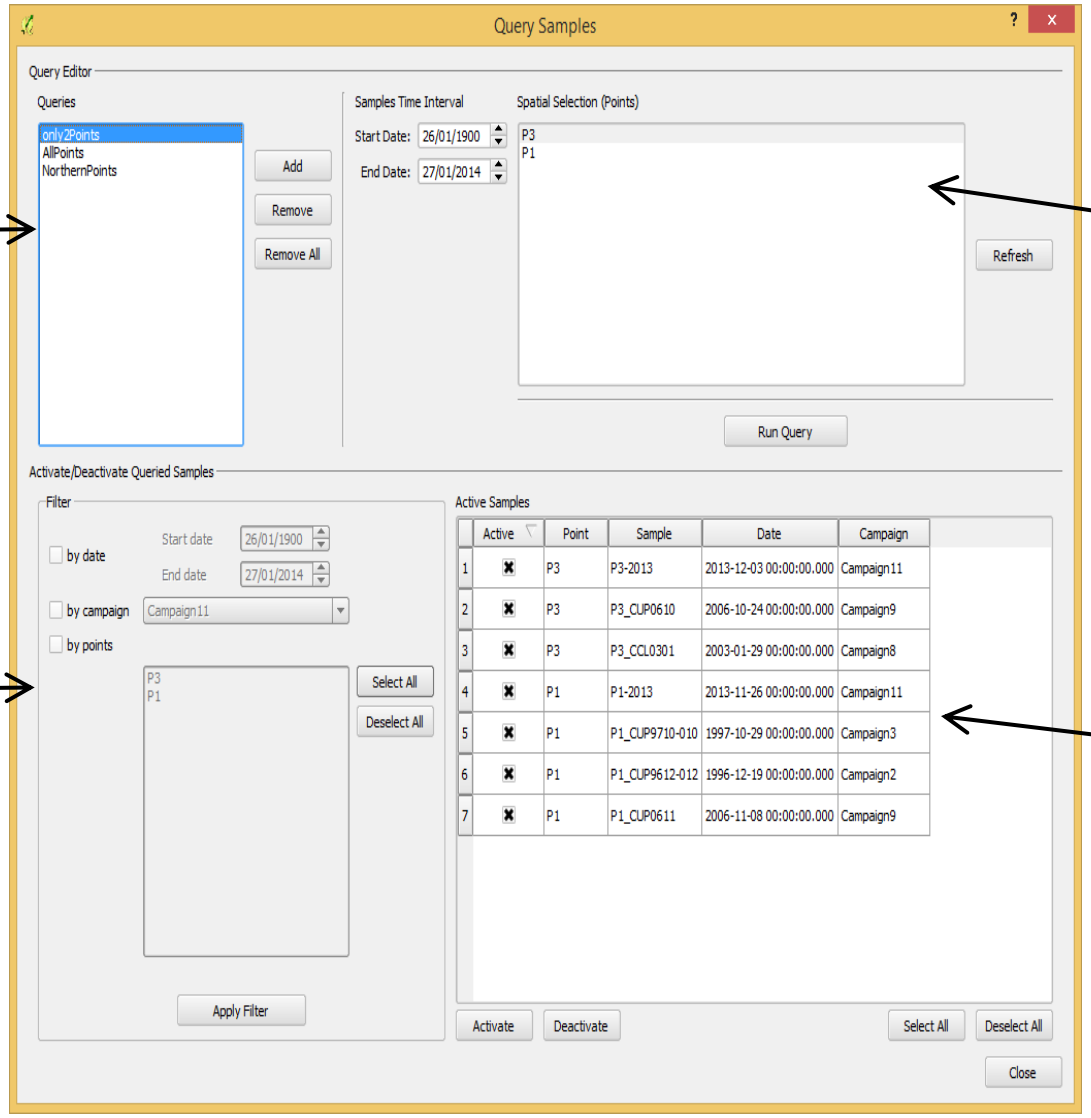
Hydrochemical Sample Selections

Save selections of samples for later use

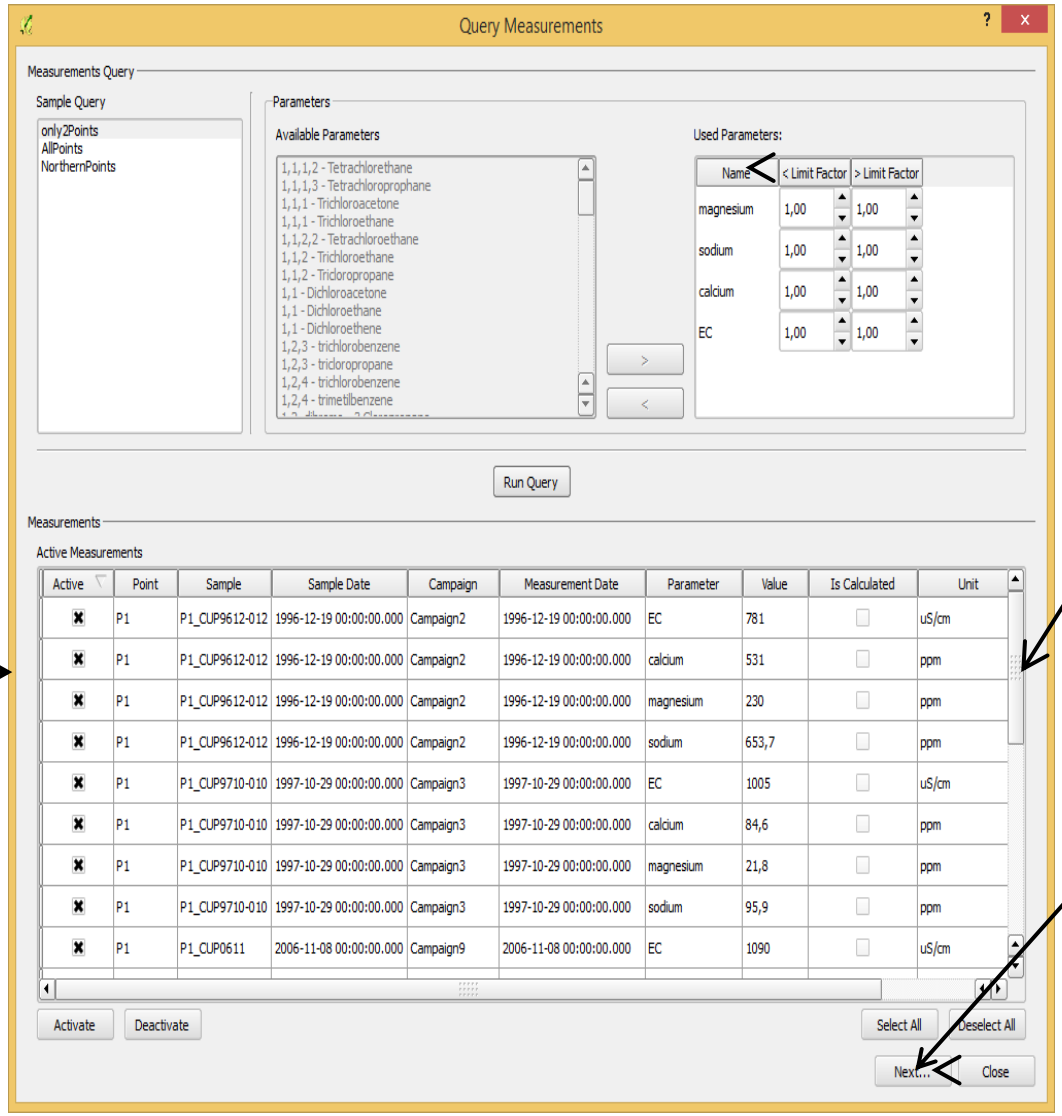
Filter by date, campaign and points

Select points using QGIS tools

Decide which samples to include in analysis



Measurements Selection Form



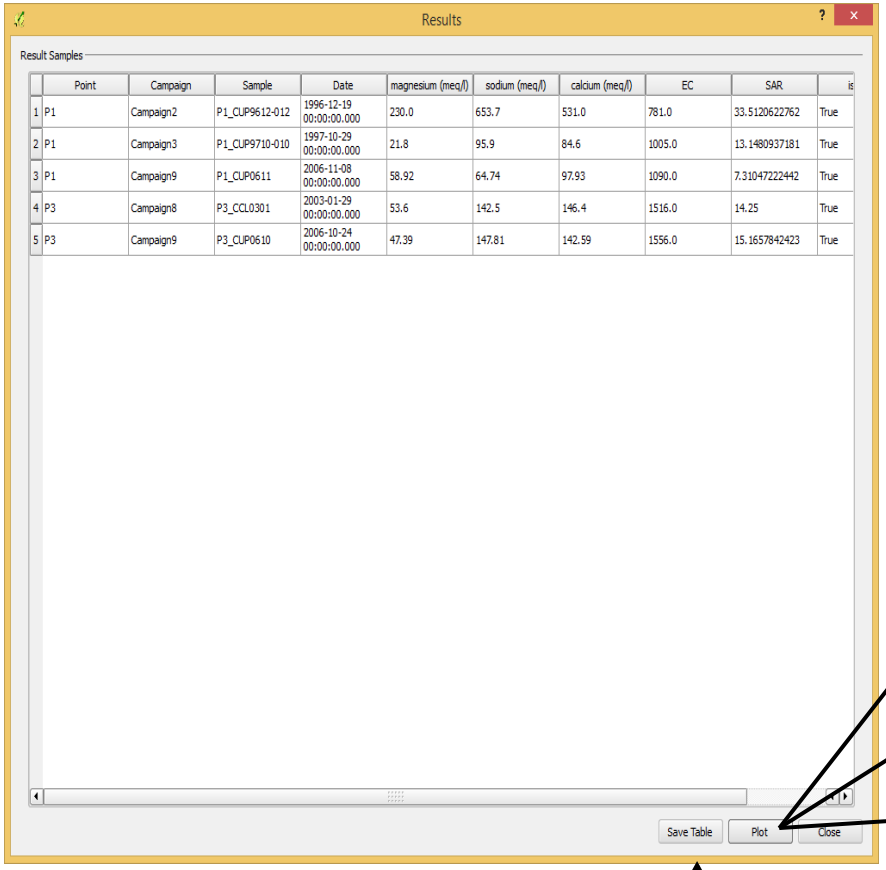
Select the parameters of interest

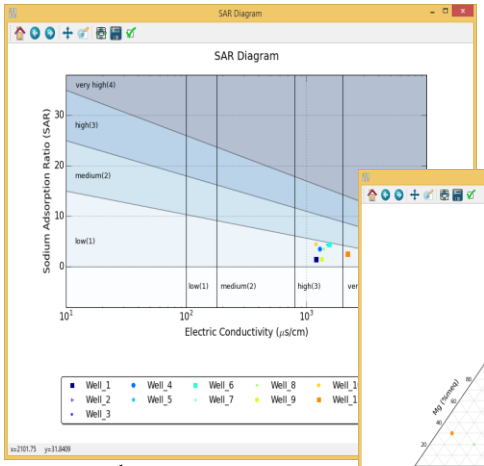
Decide which measurements to include in the analysis

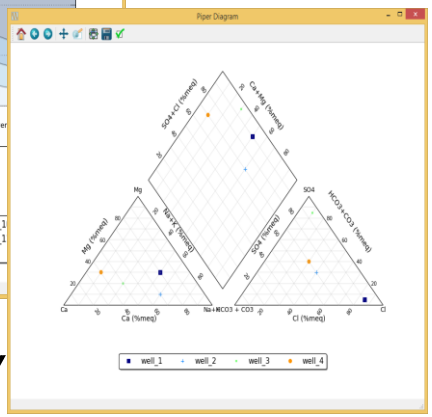
Select relevant measurements

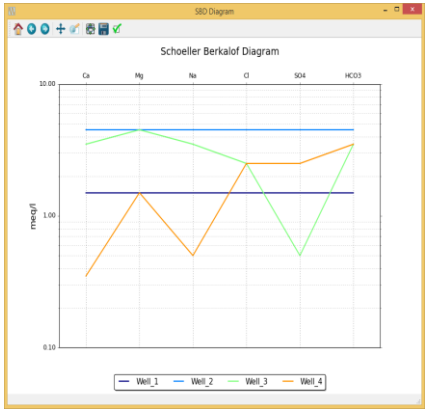
Use the selected data for charts and maps

Results Table & Plots









Save table in
OpenDocument Format

FREEWAT PLATFORM ADVANTAGES vs. commercial simulation platform

- Unite the power of GIS geo-processing and post-processing tools in spatial data analysis to that of simulation software
- The chance for public authorities to build a high informative and dynamically growing representation of a hydrologic system (i.e. river basin) where perfoming data storage and planning analysis
- WRM modules thought for decision-making and policy applications
- No cost for licences (money can be moved to development of client tailored applications)

POTENTIAL DRAWBACKS

How to manage some code interdependencies

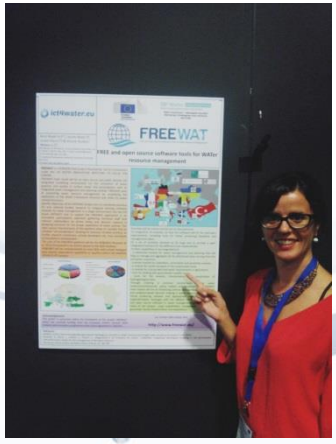
Need for continuation after project life potentially market-dependant

A GROWING LARGE COMMUNITY OF DEVELOPERS

TO BE BUILT

FREEWAT DISSEMINATION SO FAR

April 21st at Scuola Superiore Sant'Anna (Pisa-Italy)
September 14th at AIH congress (Rome-Italy).
September 22nd at ICT4Water Open Session (Barcelola-Spain)



FOSS4G SEOUL 2015
2015.foss4g.org
14th ~ 19th September 2015

European Geosciences Union General Assembly 2015
Vienna | Austria | 12 – 17 April 2015
EGU.eu

CROATIAN WATERS ON THE INVESTMENT WAVE

GIT 2015
Geology and Information Technology
IX Convegno Nazionale del Gruppo di Geologia Informatica
Sezione della Società Geologica Italiana
San Leo, 2015

AQUA2015
42nd IAH CONGRESS
THE INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS
HYDROGEOLOGY: BACK TO THE FUTURE!

FREEWAT SYNERGIES

FREEWAT

About the Cluster

Due to growing population and economy, seasonal climatic conditions have changed, including extreme events as floods and droughts. This affects as a whole the availability of water resources at world level. ICT and water efficiency is a key policy issue with potential for new research area that includes decision supporting system for the measurement of water quality and quantity including the recycling and water reuse processes. This necessitates increased interoperability between water information systems at EU and national levels and efficiency of water resources management. This site is a hub for the 10 sister projects on ICT and Water Management. Read more

Cluster Activity

SmartH2O - 3 hours ago
Check out our new video #ReducingUrbanWaterConsumption by stimulating individual and collective #ConsumerAwareness http://t.co/STeo4NI4Q0

SmartH2O - 4 hours ago
Check out our new video #ReducingUrbanWaterConsumption by stimulating individual and collective #ConsumerAwareness https://t.co/9bTh3yY2Zb

SmartH2O - 4 hours ago
RT @WaterTrends: RECYCLED BEER: Oregon is Going to Try to Make Beer Out of Sewage Water http://t.co/CKNOXkLNHs … @Beverage_World #WaterNews

Conferences

IAHR 2015

IAHR 2015
36th IAHR WORLD CONGRESS
28 June – 3 July, 2015
Delft – The Hague, the Netherlands

FREEWAT

Free and Open Source Software Tools for Water Resource Management

EU HORIZON 2020 Project

Thank you for your attention!

FREEWAT - Free and Open Source Software Tools for Water Resource Management

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SID&GRID software capabilities

A GIS platform as pre- and post-processor to simulate the hydrological cycle

Model output can be analyzed and integrated with any other

GIS-based data (e.g. for urban planning, new infrastructure design, environmental assessment, etc.)

Input and output data may be published on the web via WMS

SID&GRID project:

Simulazione e sistemi IDroinformatici per la Gestione delle Risorse Idriche

Final goal of the project

To develop a 3D physically based distributed hydrological model (surface/subsurface water) to be used as helpful tool by public bodies and/or private companies in order to simulate the whole hydrological cycle and perform spatial-temporal analysis for water management and planning

All the project was developed using **open source and free codes**.

SID&GRID architecture is based on:

1. integration of a DBMS (Data Base Management System);
2. development of tools/toolbar into a GIS framework (gvSIG);
3. integration and development of groundwater (saturated and unsaturated zone) and surface water hydrological modeling codes in the GIS platform.

SID&GRID hydrological model (1)

SID&GRID numerical core is composed by a set of numerical packages, derived by the well-known MODFLOW "family" (U.S. Geological Survey): the user can simulate the whole hydrological cycle or just parts of it.

In red: tools specifically developed or adapted in SID&GRID.

1. Groundwater flow, activating one or more "stresses":
    - Effect of Well(s)
    - Interaction with River/Streams or Drains
    - Direct aquifer recharge
    - Other boundary conditions (e.g. constant head, general head bnd., etc.)
2. Water flow in the unsaturated zone with two options:
    - 1D infiltration model (with evapotranspiration)
    - Full 3D solution (+ evaporation, transpiration, pond, seepage flow)

SID&GRID hydrological model (2)

3. Water flow in stream/river (1D Saint-Venant eq. (kinematic—wave approximation) and interaction of surface/subsurface flows.

4. Possibility to activate Local Grid Refinement(s) in selected areas of interest, and there solve the full 3D unsat. zone (LGR VSF).

5. Overland flow (a new MODFLOW package to be connected with UZF or VSF)

6. New Jython algorithms (directly embedded in gvSIG -) to compute:

   the PET (Potential Evapotranspiration) term; Canopy interception: the net rainfall rate reaching the soil surface.