FREEWAT

Free and Open Source Software Tools for Water Resource Management

EU HORIZON 2020 Project

Scuola universitaria professionale
della Svizzera italiana

SUPSI

H2020 FREEWAT

Lugano Lake case study

European Commission

ict4water.eu

Participatory Approach : Local Focus Group

Primary concerns:

-***Phosphorus load*** *being delivered to the lake.*

- *The primary concern for all stakeholders is the water quality of the lake. Can surface water be managed better to reduce phosphorous load to the lake. Is phosphorus entering the lake through the groundwater significant and must/can this be addressed?*

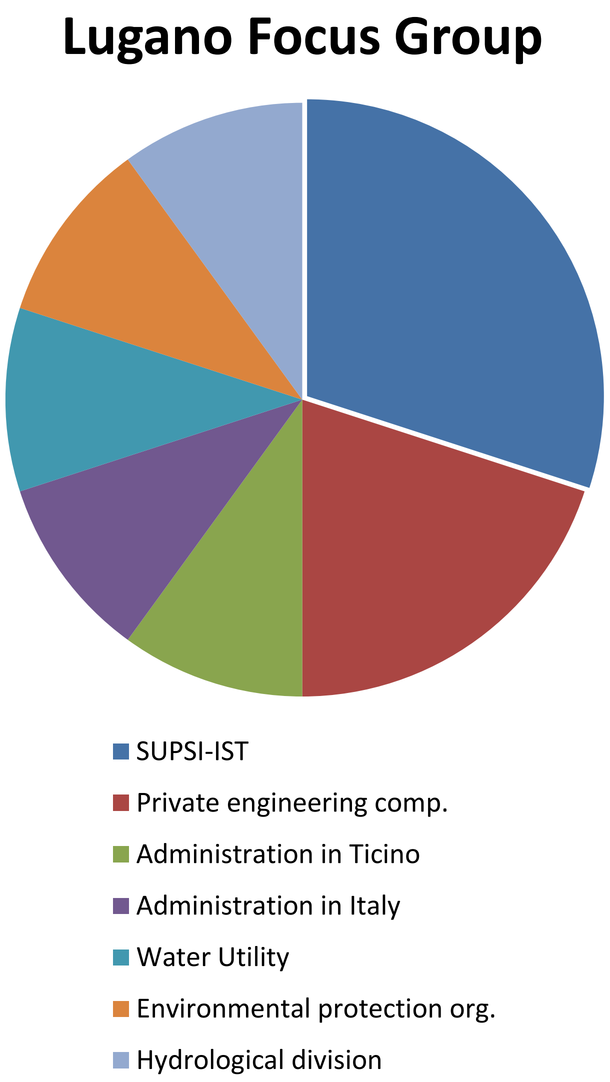
-A model that can be used for ***transport simulation*** *of a variety of species (phosphorus, nitrogen, pesticides)*

-The possibility to simulate spills for emergency response

-Delineating water protection zones

This topic is very relevant, in the past as a result of an increase in the population and internal migration, the lake became strongly eutrophic with the P concentration reaching 140 mg/m^3. Monitored values in 2014 indicates values that still do not meet the objectives of the lake recovery program.

As no GW model existed to date, the application of FREEWAT will enable a better understanding of the lake-GW interactions so that new policies and actions can be designed.



Climate change prognosis for the Southern Alps

FREEWAT

The expected conditions in the region are available with low level of confidence but clearly show a substantial impact on the water cycle:

- Temperature: + 1.8 °C (0.9 to 3.1) in winter and
  +2.8 °C (1.5 to 4.9) in summer
- Precipitation: +11% (1 to 26) in winter and
  -19% (-6 to -36) in summer

Previous hydrologic investigations show that this is likely to impact the groundwater (aquifers and springs), the river discharges and consequently to the water availability that could be, in some period of the year, limited.

Increased rains in winter and reduction in summer means **less frequent** but **more intense** precipitations. This would produce higher run-off but at the same time **less infiltration**, **reducing the aquifer recharges**. At the same time, higher temperature would produce **higher evapotranspiration** and evaporation **increasing the water losses**.

Water usage in the CH part of the basin

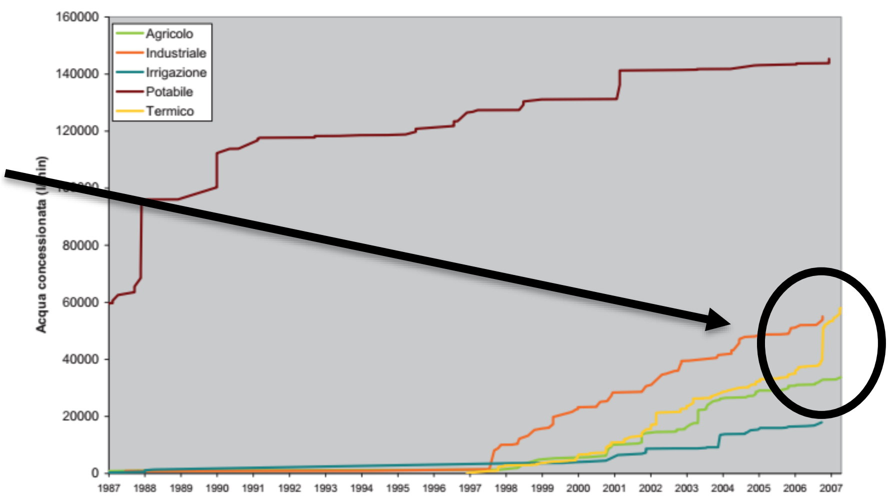
Currently the drinking water sources are:

41% groundwater, **40% springs** e **19% surface water**.

Pro-capita use (PE) is grown until the 70s, then it remained constant in the following 15 years and finally decreases slowly but constantly until today. The identified reasons for this decrease are:

- Structural renew of the industrial sector with internal recycles
- Installation of water counters
- Informative campaigns for a parsimonious use of water
- Renew of the supply infrastructure and decrease of leaches

A very interesting tendency is the constant increase of geothermal concession requests. Even if it doesn't directly affect the water quantities, this increase the exposition of the water resource to quality issues.



Individuated objectives

1. Implement a model that can be used to investigate the water budget, particularly with the **evaluation of groundwater-lake interactions**, and potential contamination problems.

2. Better **understand the existing dynamics** of groundwater and surface water.

The case study is also an opportunity to test two modules developed in SUPSI:

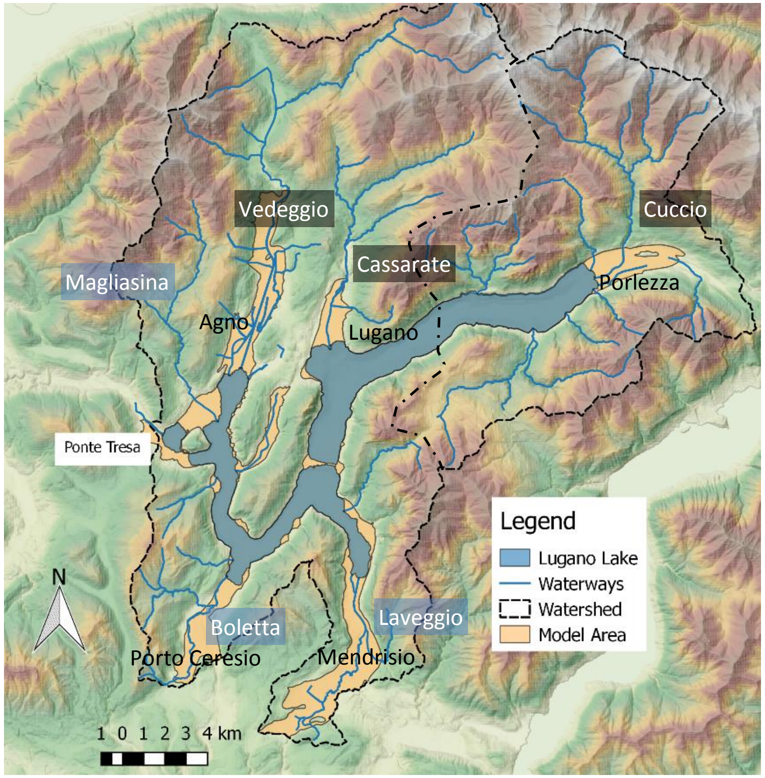
- **Observation Analysis Tool (OAT)**, used to integrate time-series data into the modelling platform.
- **Lake package (LAK)**, used to simulate the dynamic interaction between the lake and the aquifers.

The Lake Lugano basin

The lake resulted from fluvial erosion of a tertiary canyon which underwent a strong morphological overprint during the Pleistocene and Alpine glaciations. The basin have 5 major rivers and a single outlet. Additionally, the lake is fed by a large number of mountain streams and rivers, most of which are ungagged.

Height: 271 m.s.l.m.
Surface: 48.9 km2
Volume: 5.86 km3
Max depth: 288 m
Population: 266'059 ab.
Geology: rocce calcaree, gneiss e porfido

Main aquifers: Porto Ceresio (IT), Porlezza (IT), Lugano (CH), Agno (CH), Mendrisio (CH).
Tmain tributaries: Vedeggio (3.74 m3/s, 6.8 km2)
Cassarate (2.33 m3/s, 72 km2)
Cuccio (2.2m3/s, 53,8 km2)
Emissary: Tresa (21.35 m3/s)

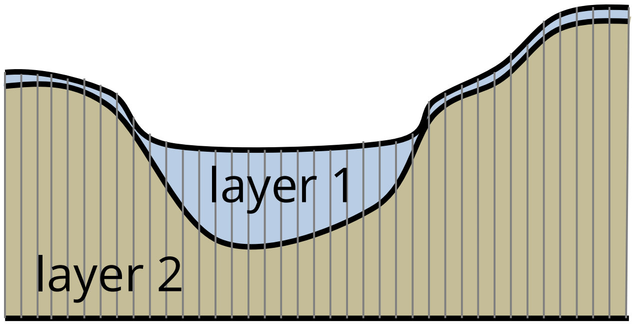


Domain

Horizontal grid: 150 m

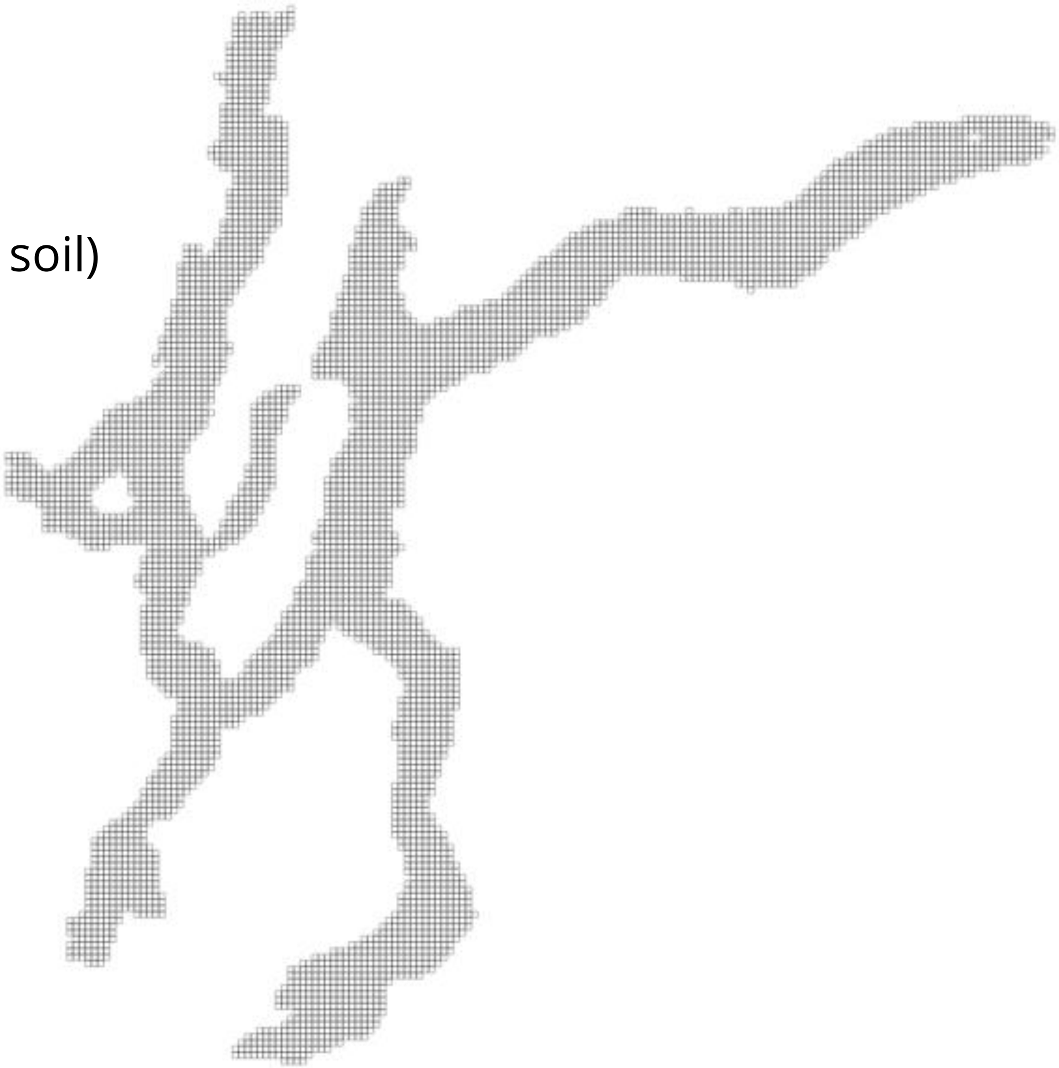
Vertical discretization: 2 layers
(layer 1 for the lake e layer 2 for the soil)

Temporal resolution: weekly



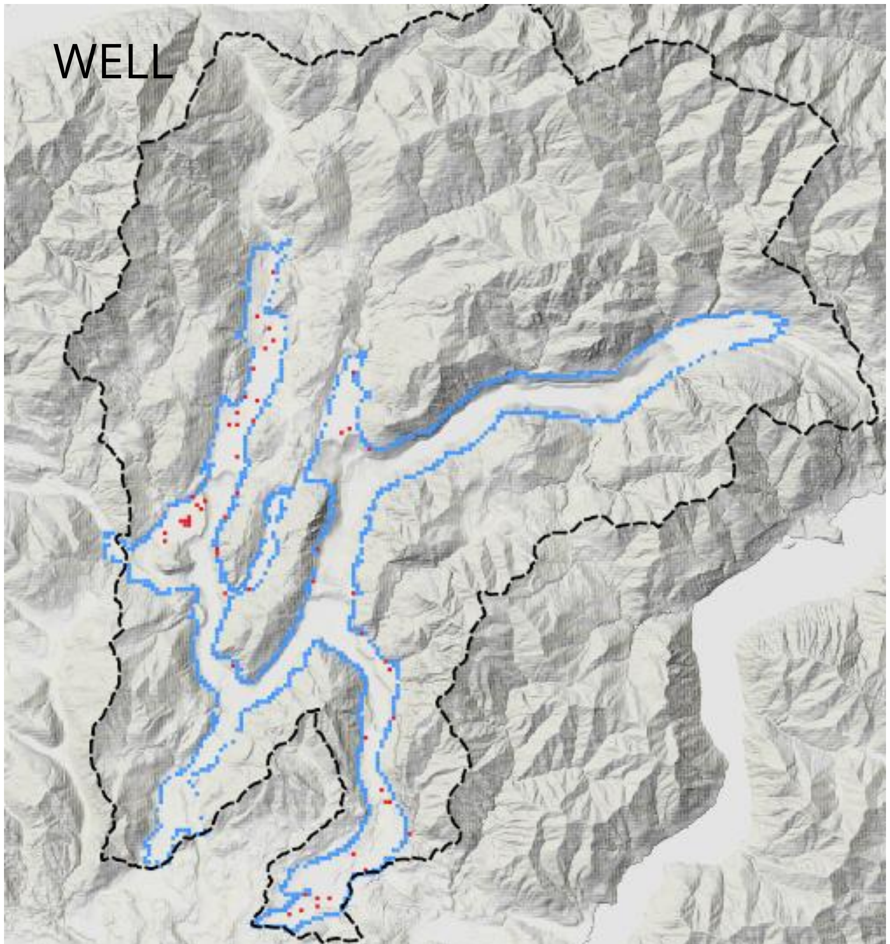
173 rows x 171 cols
(29'583 cells):

- 4'980 "active" in Layer 2
- all "inactive" in layer 1
- 2'578 of layer 1 are "lake"

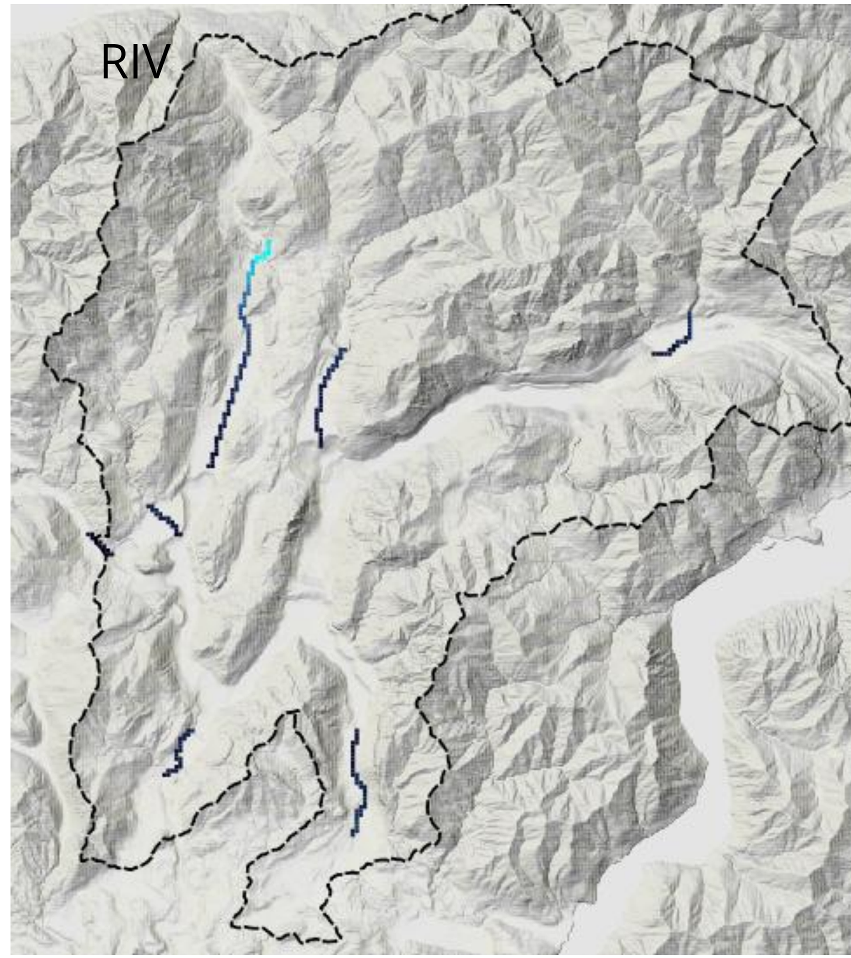


Boundaries conditions

Recharges and losses: input from statistics of surface water models results

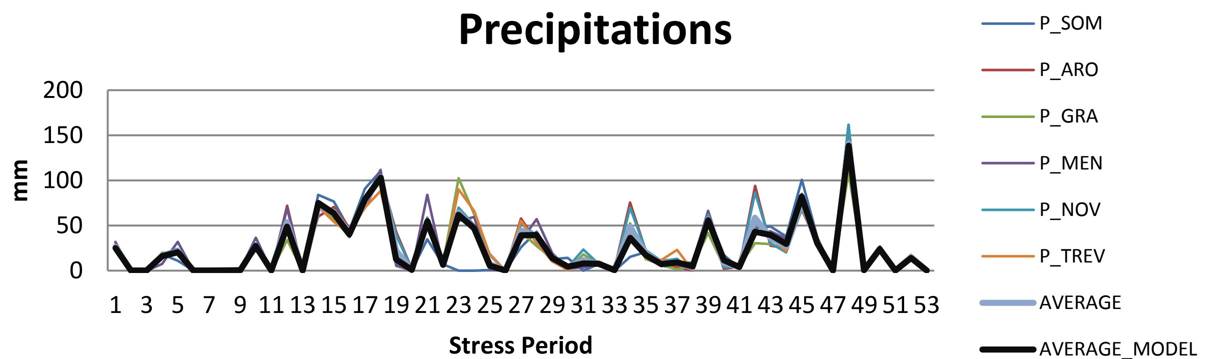


River stages = DTM + mean monthly level variations from observations and interpolated along the river where the lake level is set at the outlet.

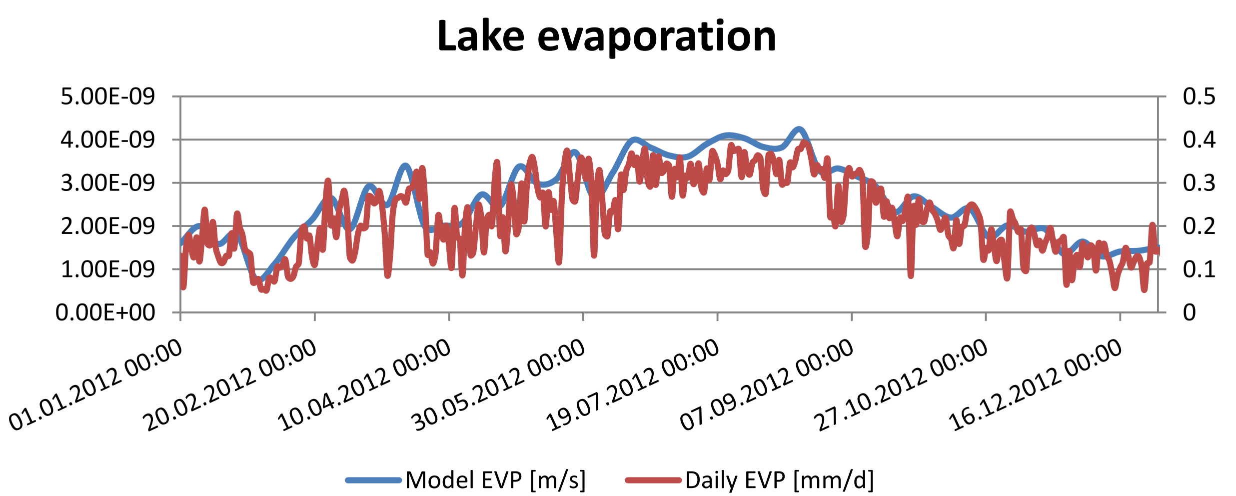


Boundary conditions using OAT

Sensor Name	Description	Altitude
P_SOM	loc_Somazzo	527
P_ARO	loc_Arosio	860
P_GRA	loc_Grancia	310
P_MEN	loc_Mendrisio	289
P_NOV	loc_Novaggio	620
P_TRE	loc_Trevano	342

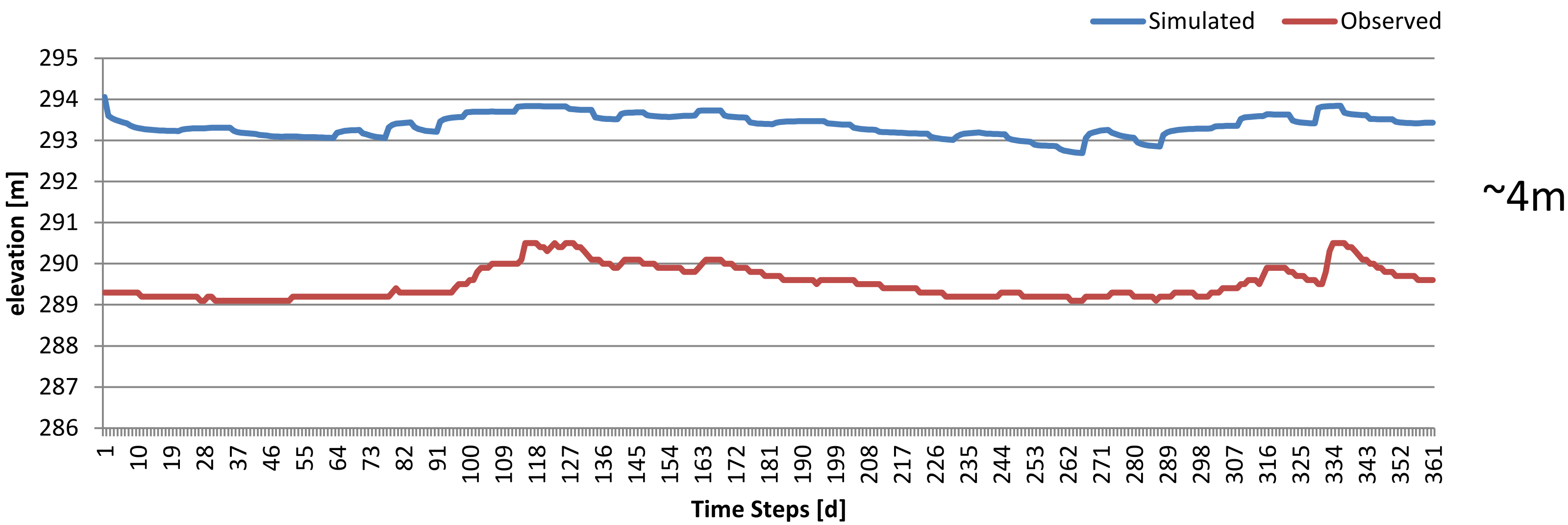


Uutsed in RCH (infiltrtion), WELL (surface input), LAK (direct in). **Imported and aggregated in OAT**



Used in the LAK (direct evaporation) and **calculated with the OAT method of Hargreaves**

Results



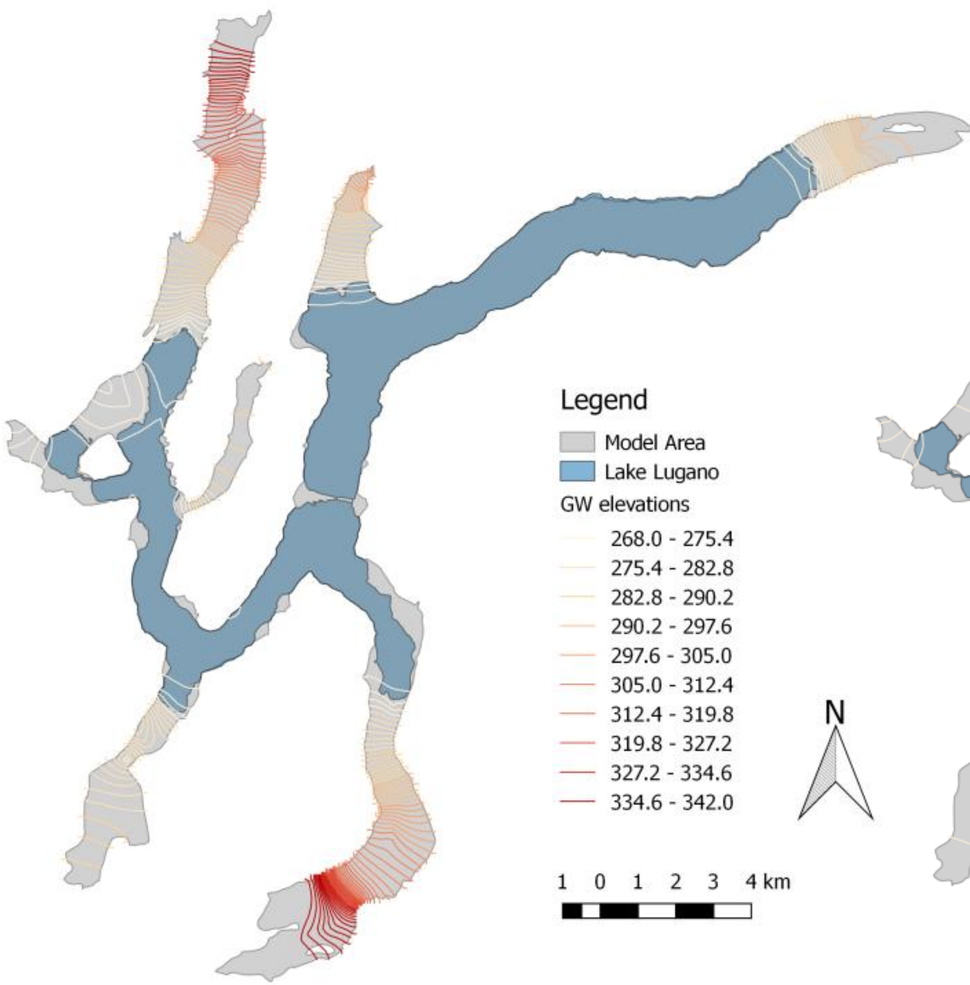
The presented **results are not optimal:**

- Data are transboundary: not always aligned, available and compatible
- The case study is very complex and several assumptions / simplifications were used (one geological layer)
- Manual calibration only since Automatic calibration of the RIV, LAK & WELL packages is not yet supported in FREEWAT.

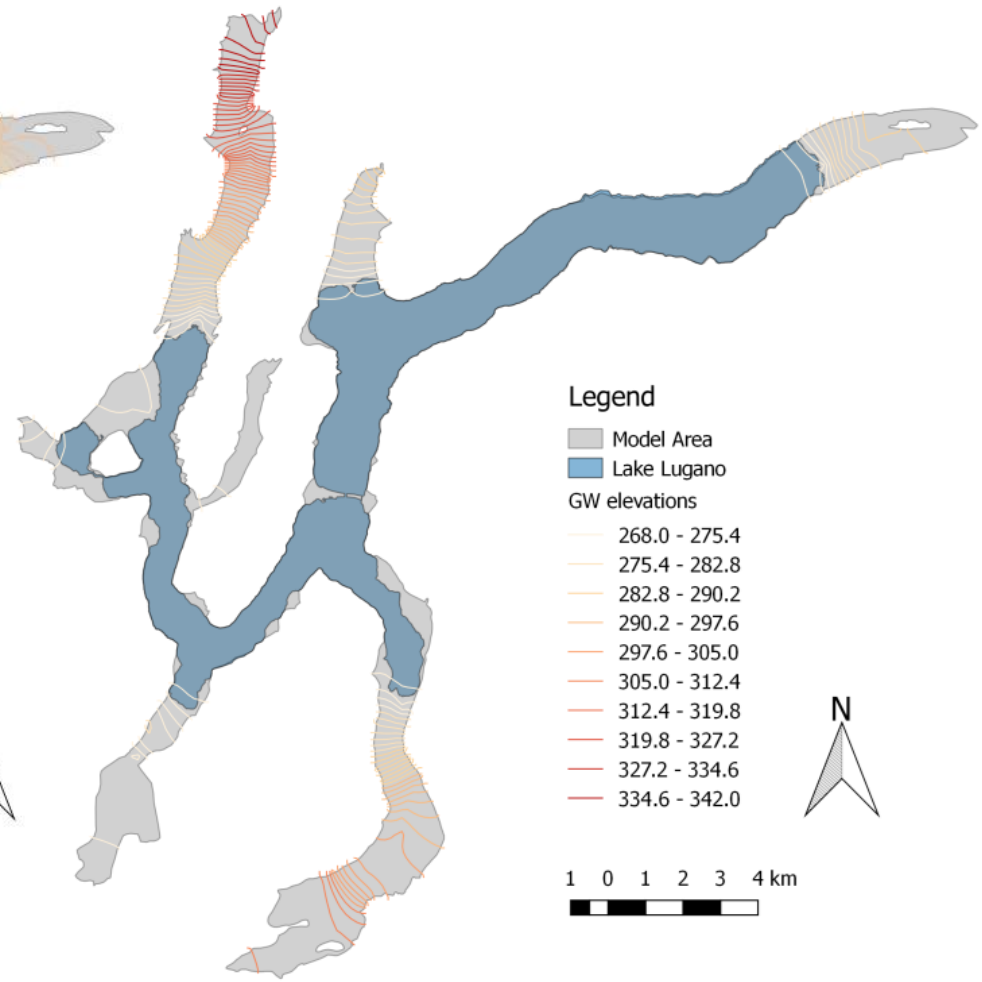
Nevertheless they provided valuable insights to understand the integrated (aquifer / lake / river) dynamics

Results

June 2013

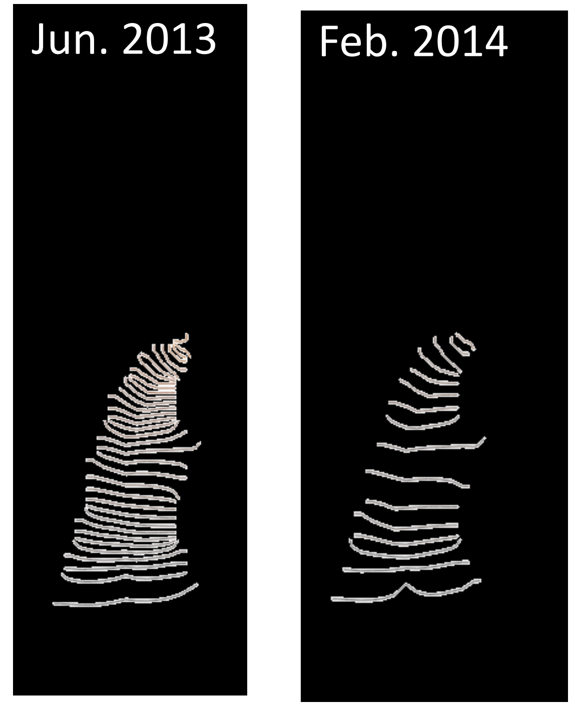


February 2014



The river-aquifer interaction varies

Veddeggio



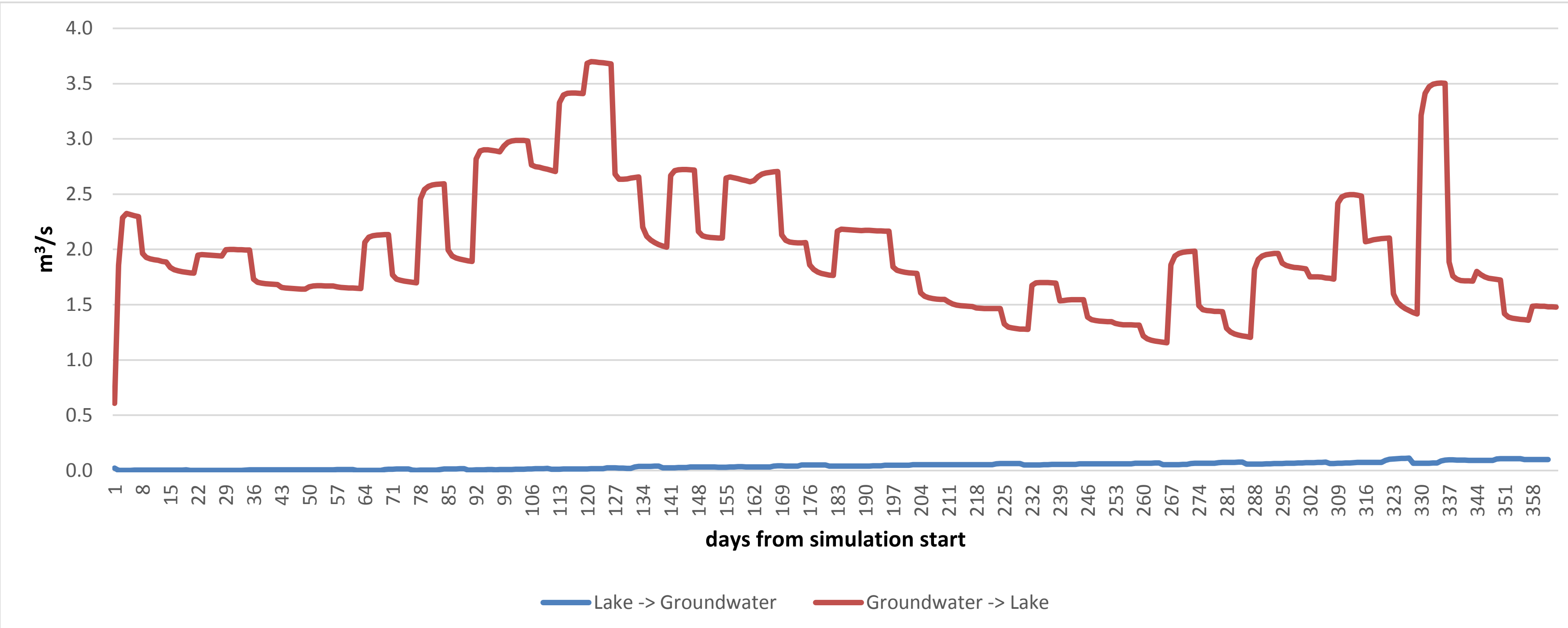
Casserate

The interaction is different in different aquifers:

- Vedeggio drains the aquifer all year long (with varying intensities)
- Cassarate feed the aquifer all year long (with varying intensities)

This has a great impact on pollutants and nutrients dispersion !

Water exchanges

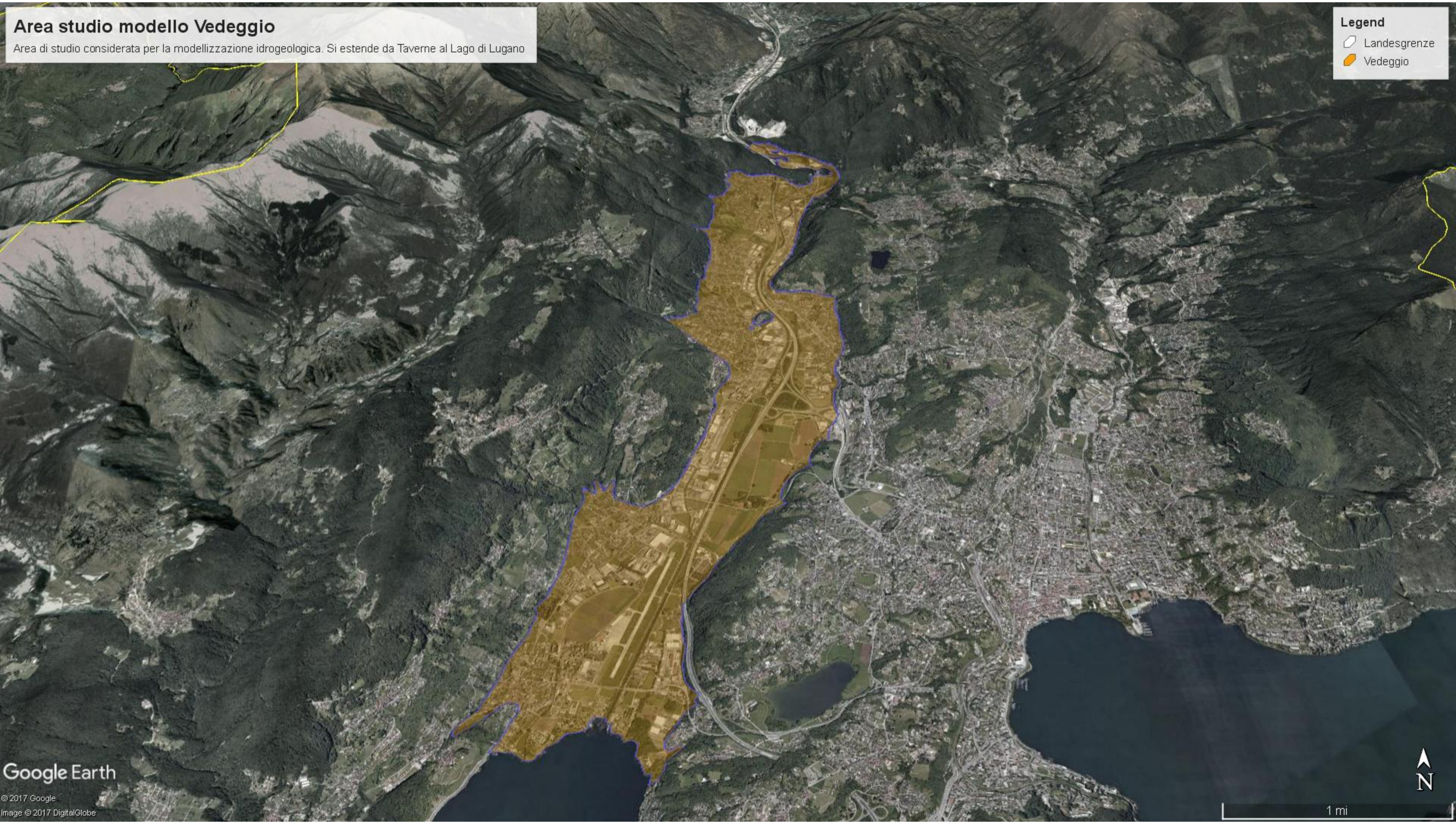


Most of the fluxes are directed from the groundwater to the lake, while only marginally the opposite occurs:

→ the nutrients and pollutants in the soil may contribute to lake quality (up to now only surface water was considered!)

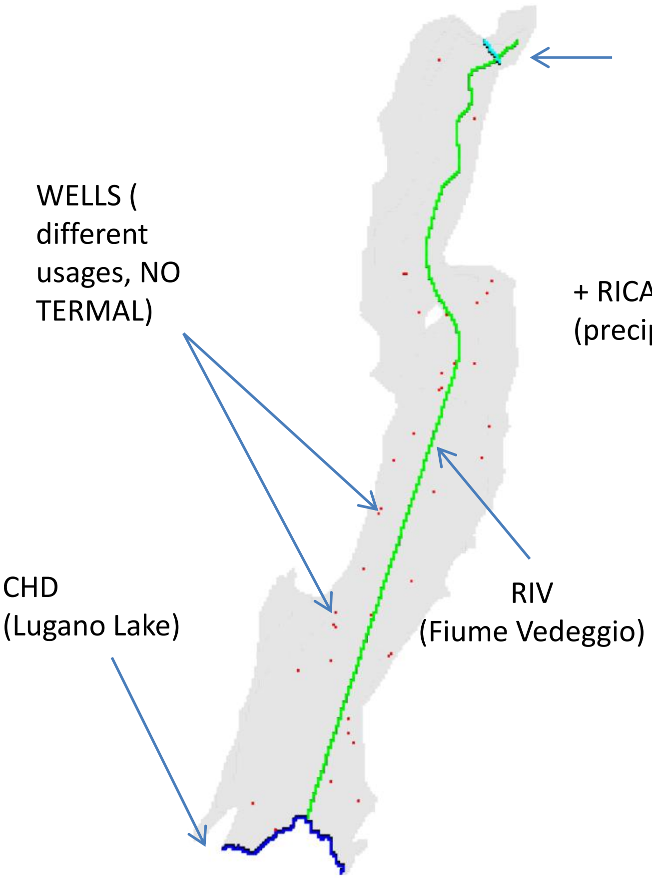
Specific sub-model of on Lake Lugano:
the Vedeggio aquifer

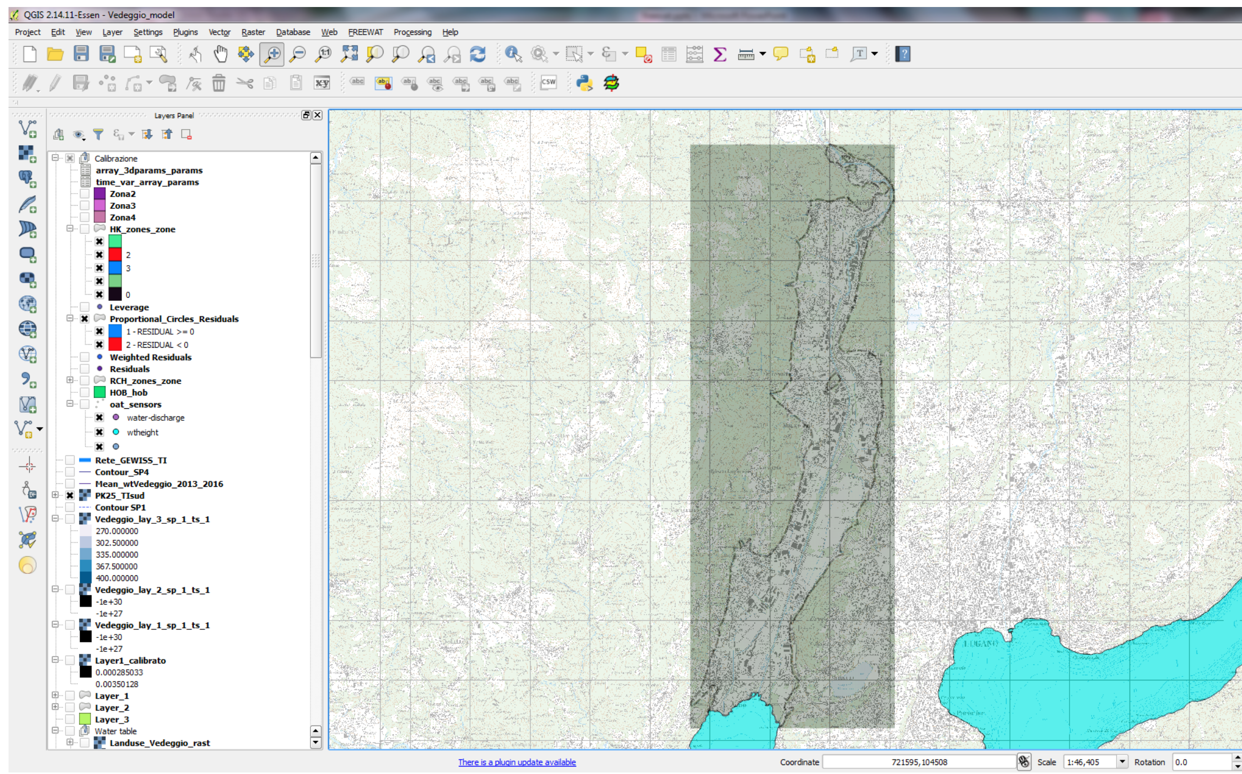
Study area



Area studio modello Vedeggio
Area di studio considerata per la modellizzazione idrogeologica. Si estende da Taverne al Lago di Lugano
Legend
Landesgrenze
Vedeggio
Google Earth
© 2017 Google
Image © 2017 DigitalGlobe
N
1 mi

The model components





Model settings

Horizontal resolution : 25m (DEM)

Vertical discretization: 3 layers, two 20m + one 40m (first two layers include 87% of the wells)

Temporal discretization: 5 Stress Periods

-**1 Steady State** of 1 day → Yearly average conditions

- 4 transient periods, 1 for season:

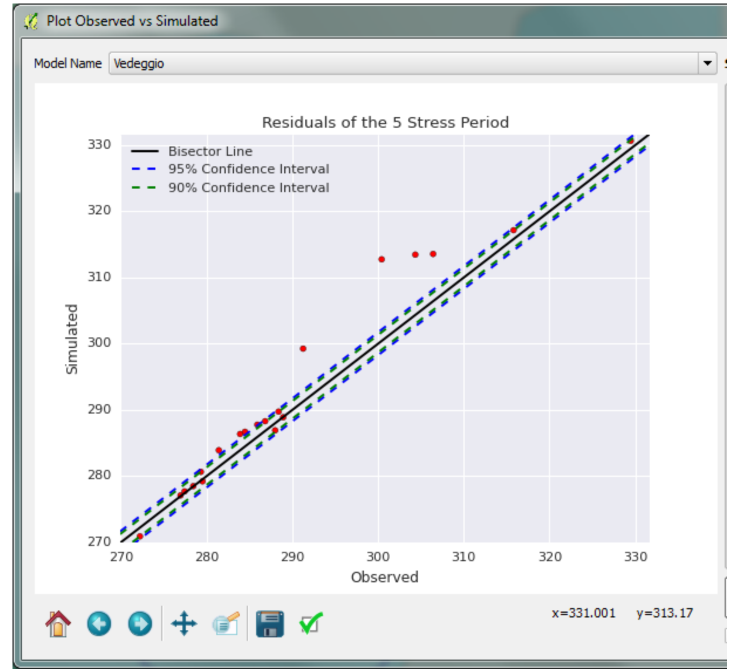
- Average **spring** conditions (01 Mar – 30 Jun);
- Average **summer** conditions(01 Jul – 31 Aug)
- Average **autumn** conditions(01 Spt – 30 Nov)
- Average **winter** conditions(01 Dic – 28 Feb)

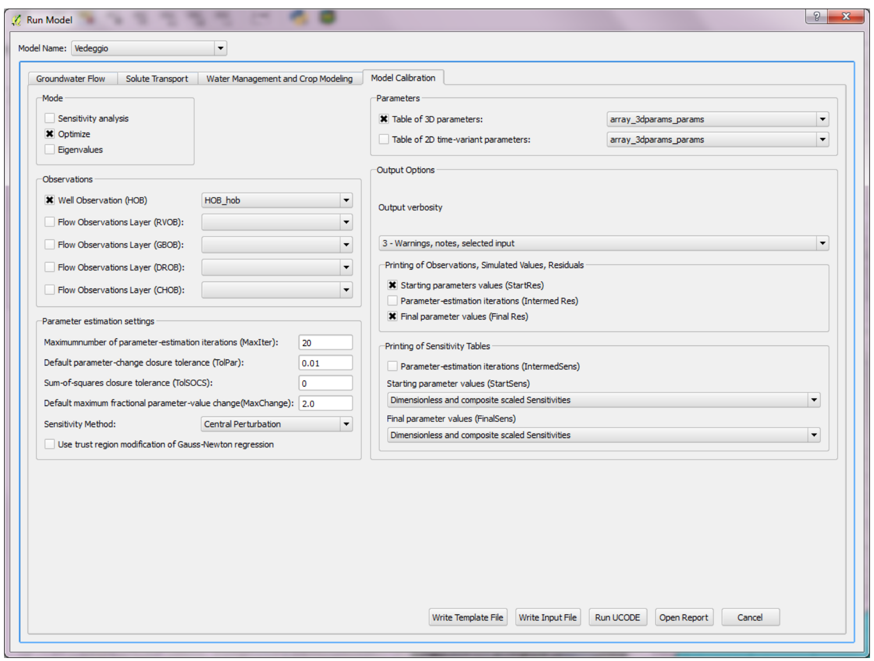
Average conditions derived from the observations in the period 2013-2016

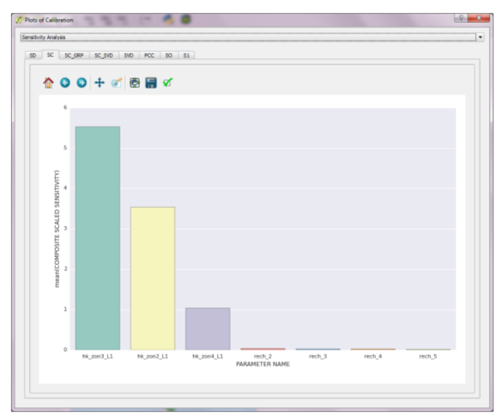
UCODE : sensitivity analysis and inverse modeling

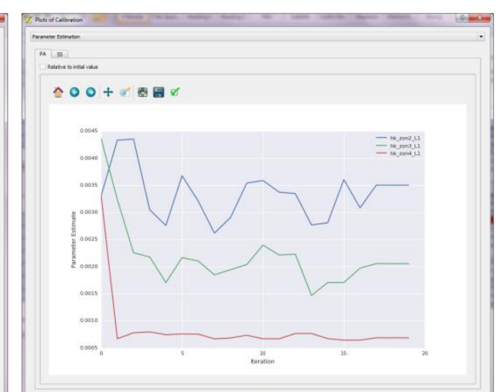
- 20 piezometers monitored* 5 SP = 100 targets fro calibration

- Sensitive analysis: hydraulic conductivity
- Calibration of 3 main zones

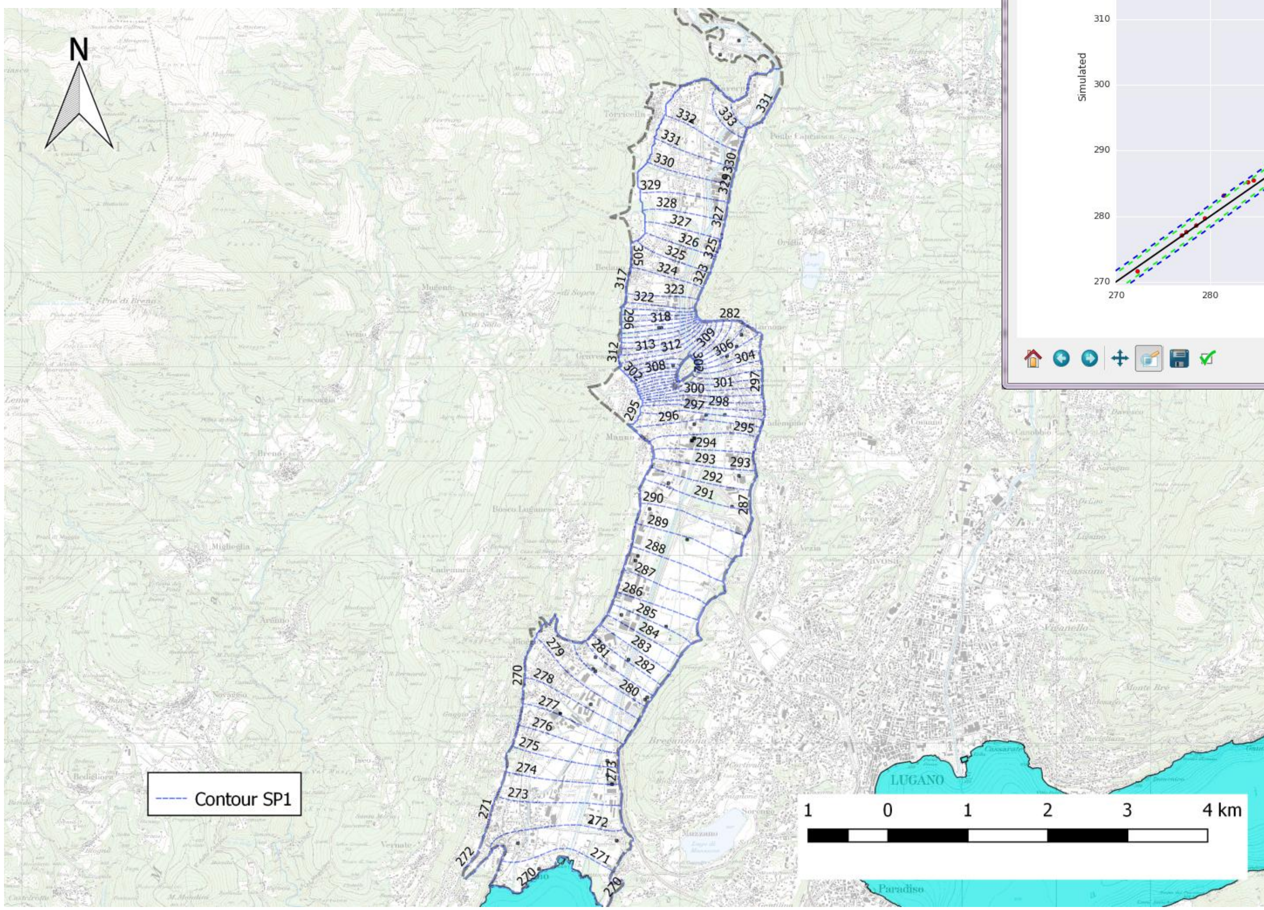


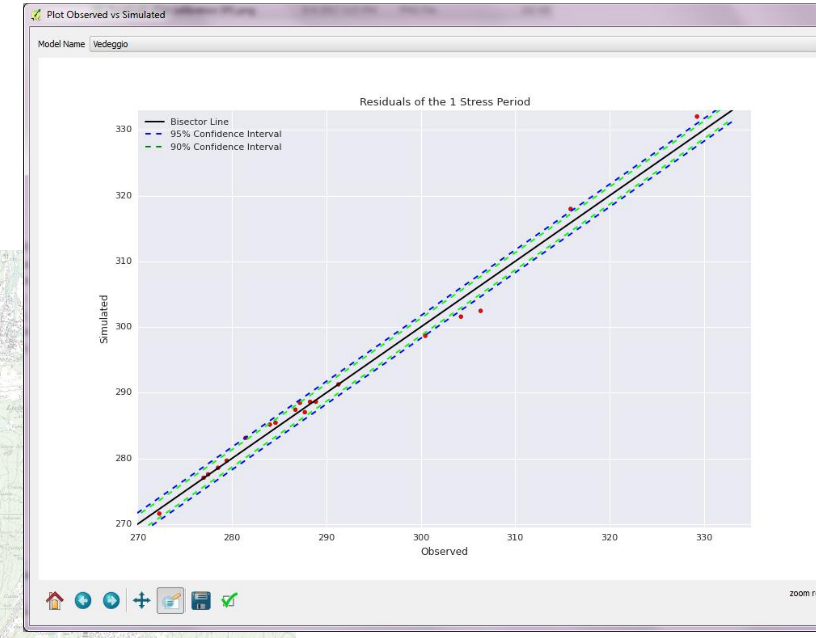




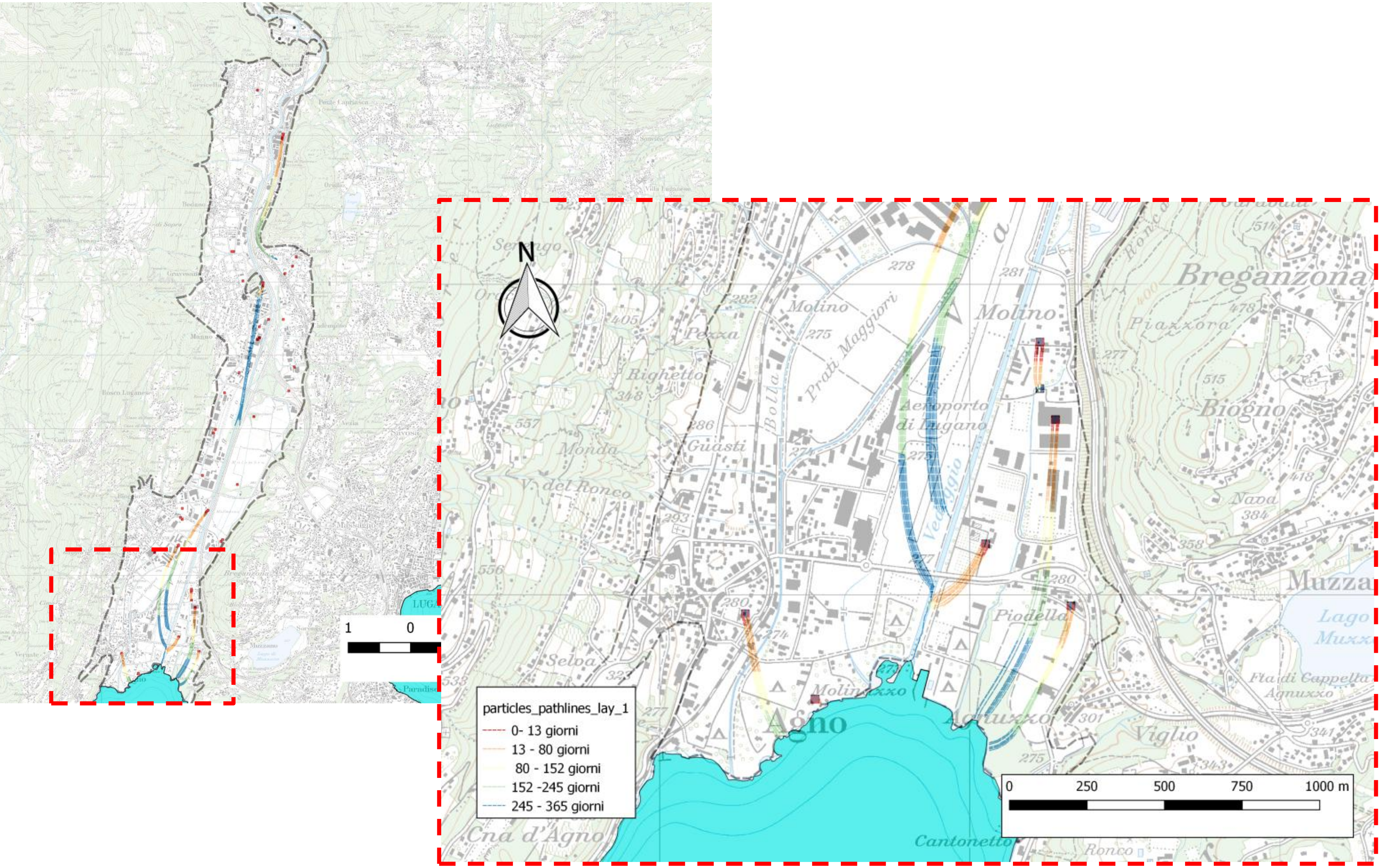


Model fit


N
Contour SP1
1 0 1 2 3 4 km
LUGANO
Paradiso


Plot Observed vs Simulated
Model Name Vedeggio
Residuals of the 1 Stress Period
Bisector Line
95% Confidence Interval
90% Confidence Interval
Simulated
Observed
zoom rect

MODPATH (particle tracking)



Conclusions of Case study focus group meetings

Action items

- to better understand that in the system there is a **need of integrating different types of monitoring**, each with its own characteristics and limits: satellite images, drone mapping, in-situ sensors and laboratory chemical and ecological results from specimen collection.

- The analyzed system is complex and highly dynamic so it is essential **to increase the spatial and temporal resolution of data collection** using the latest ICT technologies to capture the phenomena dynamics.

- **Models are a means** of data integration and once validated they should be used as an operative instrument for testing scenarios**, making predictions and set protection zones**.

Conclusions of Case study focus group meetings

Action items

- There is a high demand for sustainability, which should be translated **not only in the appreciated approach used in FREEWAT** of producing open source software, **but also in cost-effective solutions and open data**.

- The lake resource serves several sectors with sometime conflicting interests and thus a **participatory, well informed and shared management is essential** for societal consensus and maximization of the policy results.

- Sometimes, **the law pose fixed indicators** or objectives without considering the quick changes of the environment; **an adaptive management could constitute a better approach** to cope with climate, societal and land use changes

Thank you

Jakob, Rodolfo, Sebastian (SUPSI)

Rudy, Simone and Laura

All the Focus Group members

Mauro veronesi & Andrea (Canton Ticino administration)