SWAT 2015
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Karst SWAT hydrological modeling at large and regional scale: the case study of the island of Crete

Creating tools towards achieving WFD water quantity and quality targets

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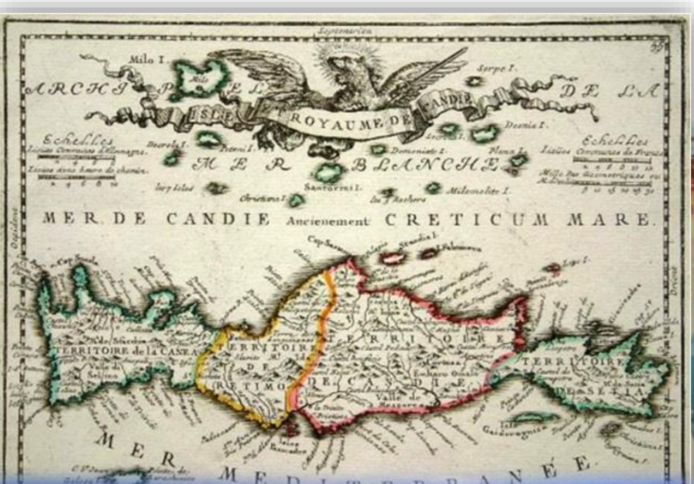

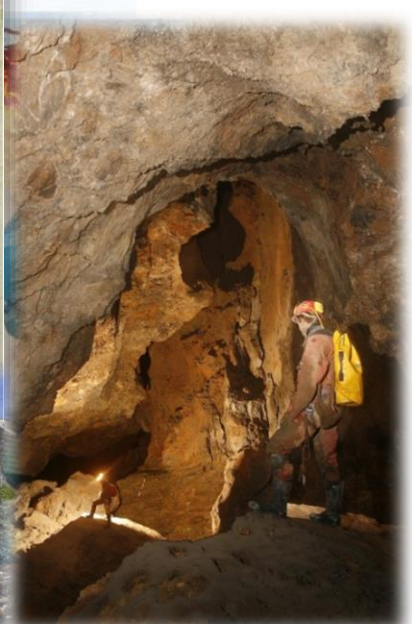

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Overview

I. Context of the research

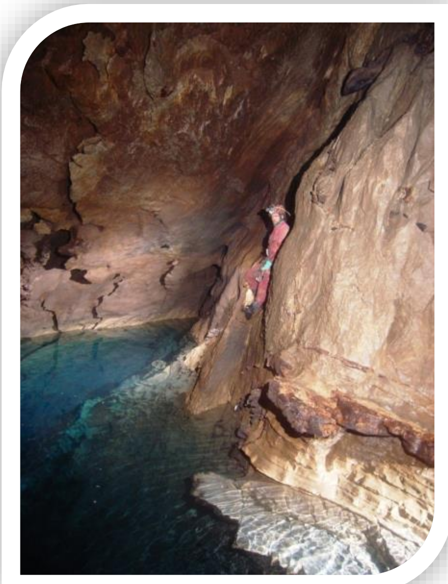
II. The karst system

III. How to model the karst system with SWAT?

IV. The case study of Island of Crete

V. Conclusion

Context



Groundwater Directive 2006/118/EC

WFD

Water Framework Directive

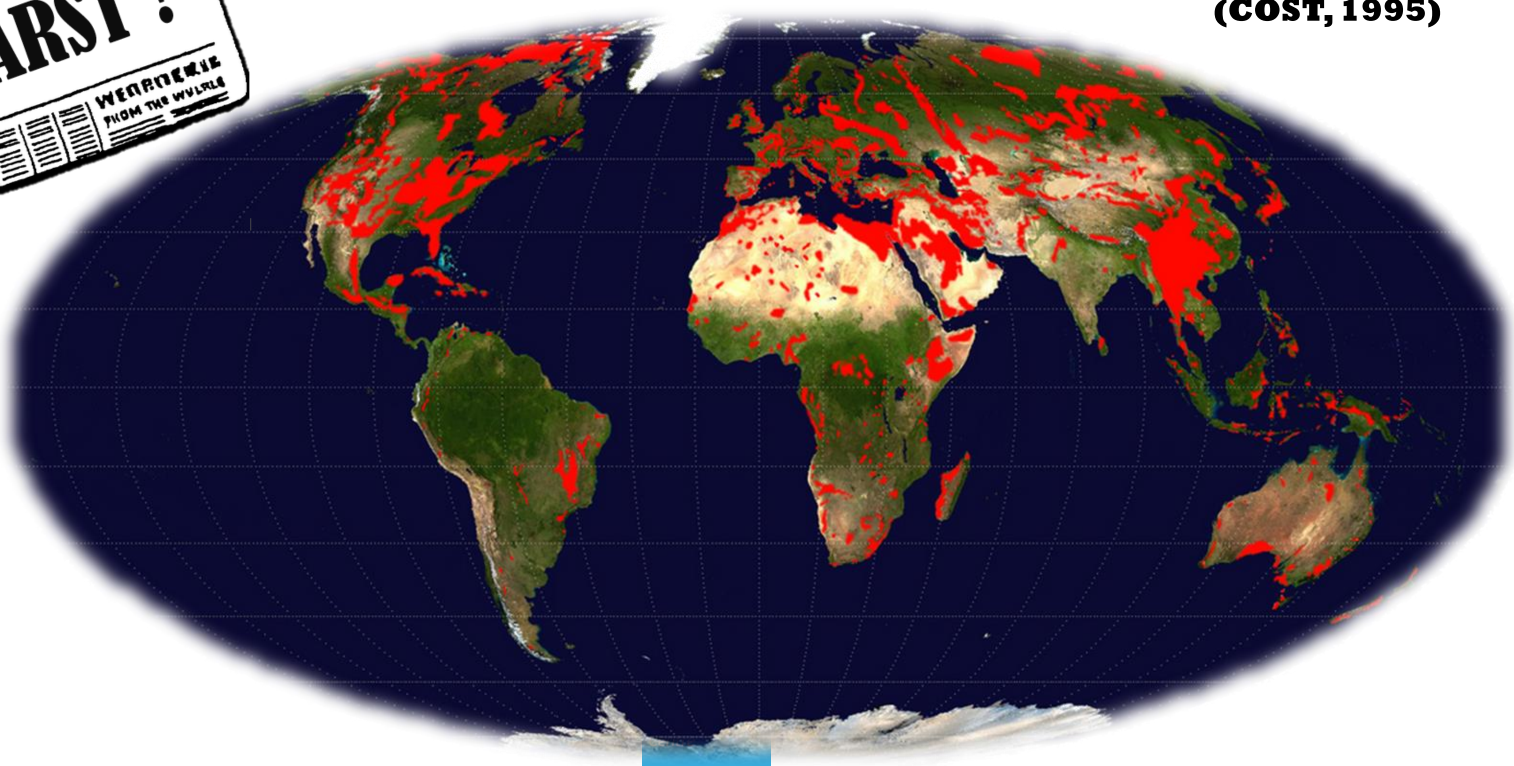
- Protection of groundwater for human consumptions:
- Study of karst system characteristics
- Identifications of hydrogeological surfaces
- Hydrogeological running and budget: Recharge, Circulation and Discharge

Karst in numbers

35% of Carbonate rock regions in Europe
(Williams and Ford, 2006)

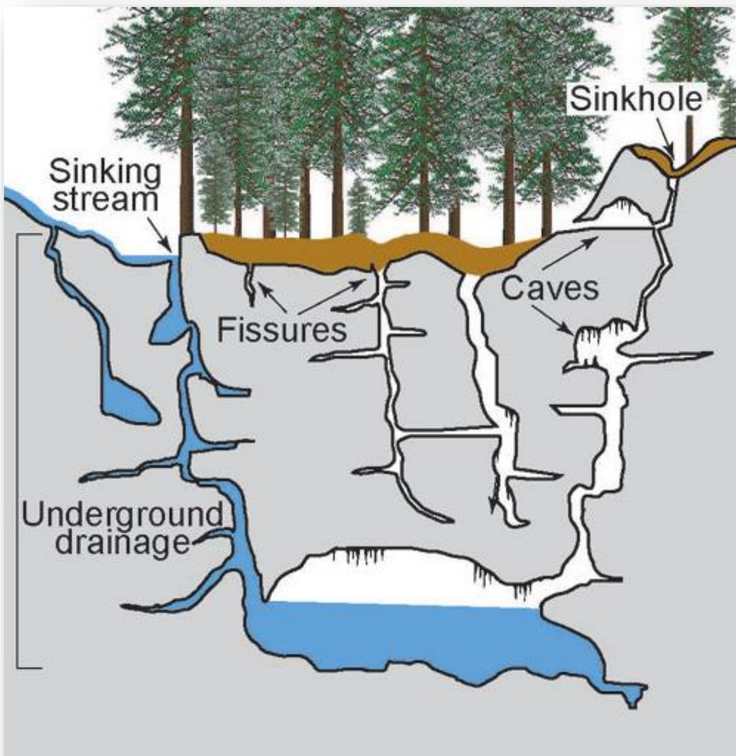
Karst regions represent 7-12% of the Earth's continental area
(Hartmann, 2014)

50% of Water supply in Europe
(COST, 1995)



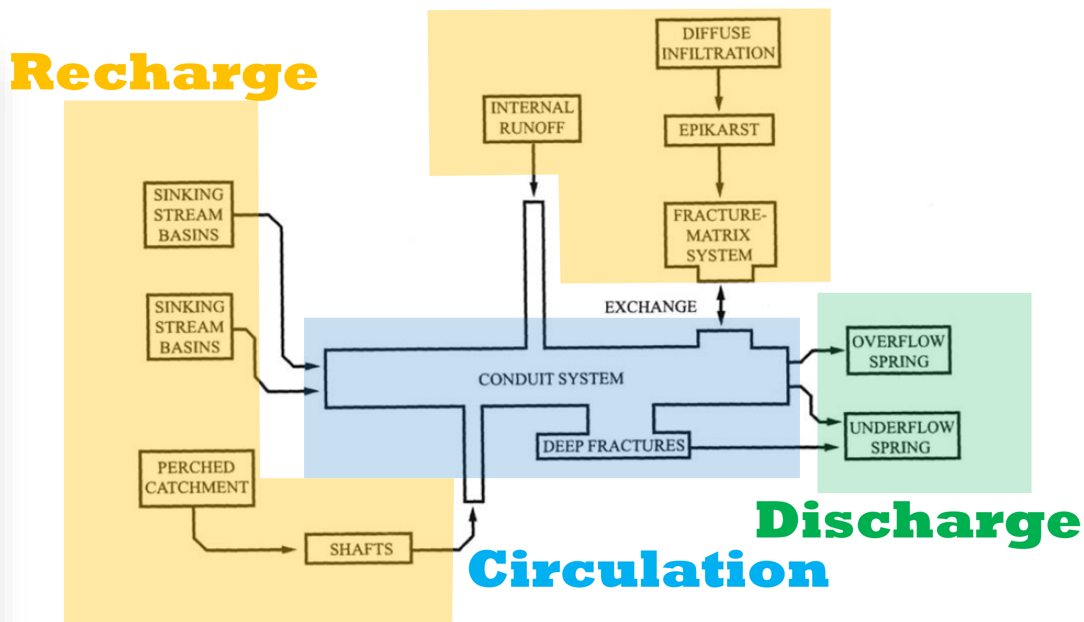
The Karst system and features

Karstic features



Conceptual model

(White W.B., 2003)



Very fast infiltration

Direct connection to the conduits below

Transfer of water in extended areas, outside the superficial subbasin delineation

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Can we model Karst system with SWAT?

Baffaut & Benson (2008)

Sinkholes ~ Ponds
(small Area and large K)

Loosing stream ~ Tributary channel
(with large K)

New richarge of deep aquifer (rchrg_krst) and consequent return flow/baseflow

Springs ~ return flow in the same subbasin

NO: transfer of water from one subbasin to another

Nikolaidis et al. (2013)

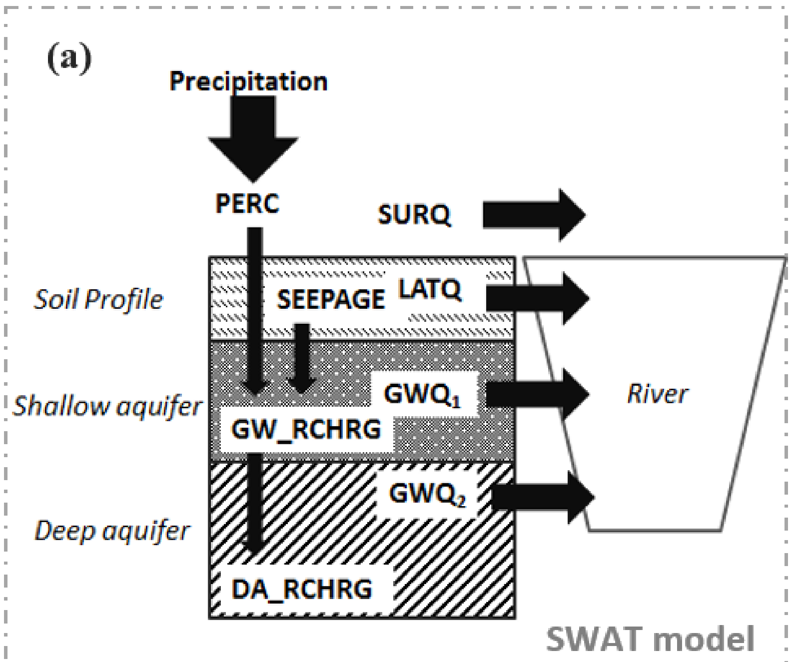
Modification of SOIL characteristics and GROUNDWATER parameters

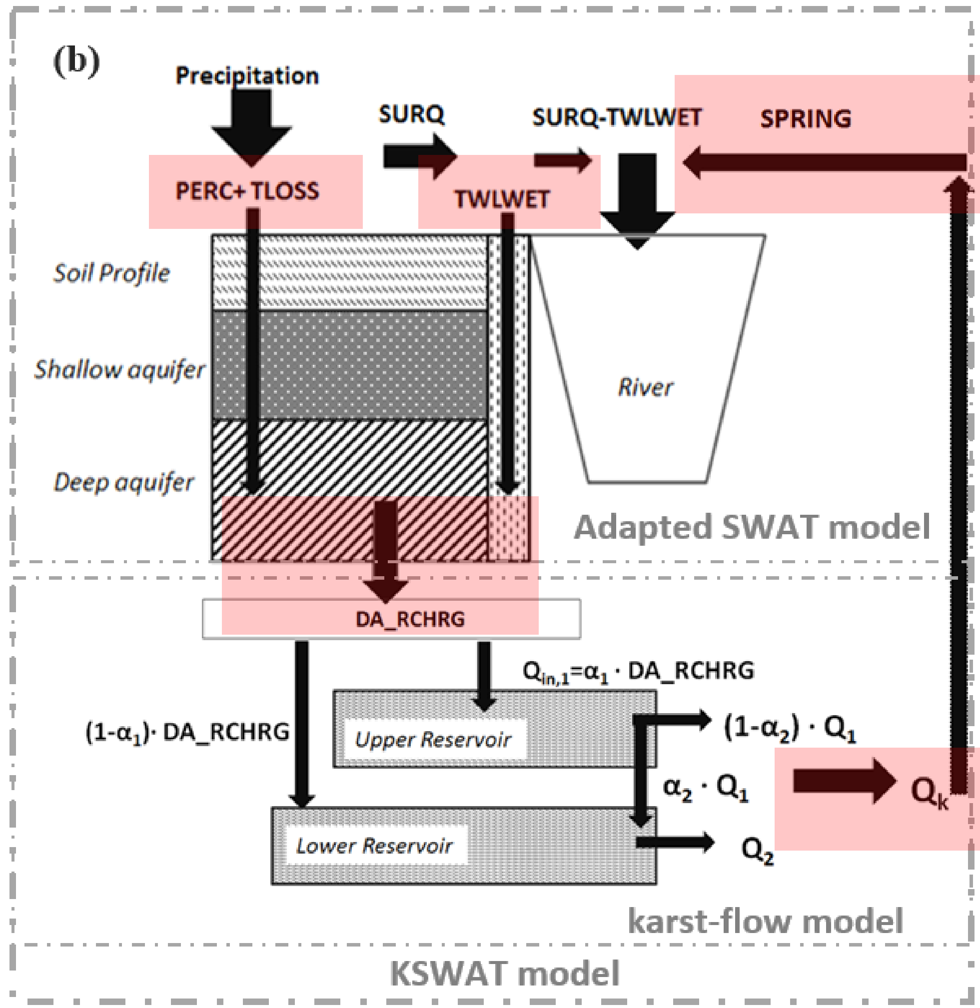
Introduction of a karst-flow model with the sum of DA_RCHRG (deep aquifer richarge) of different subbasins as input

Springs ~ point sources

YES: transfer of water from one subbasin to another

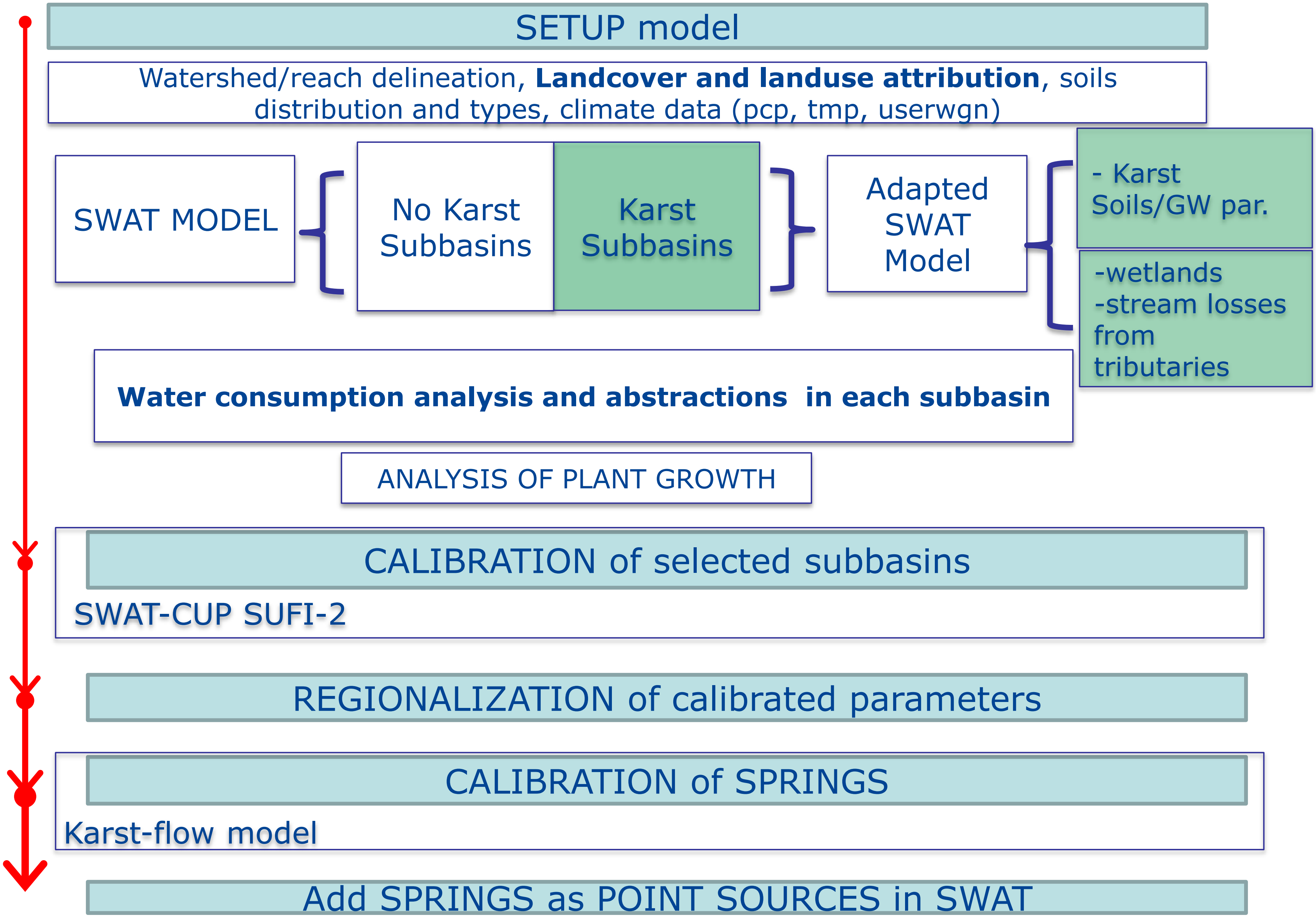
Our hybrid approach



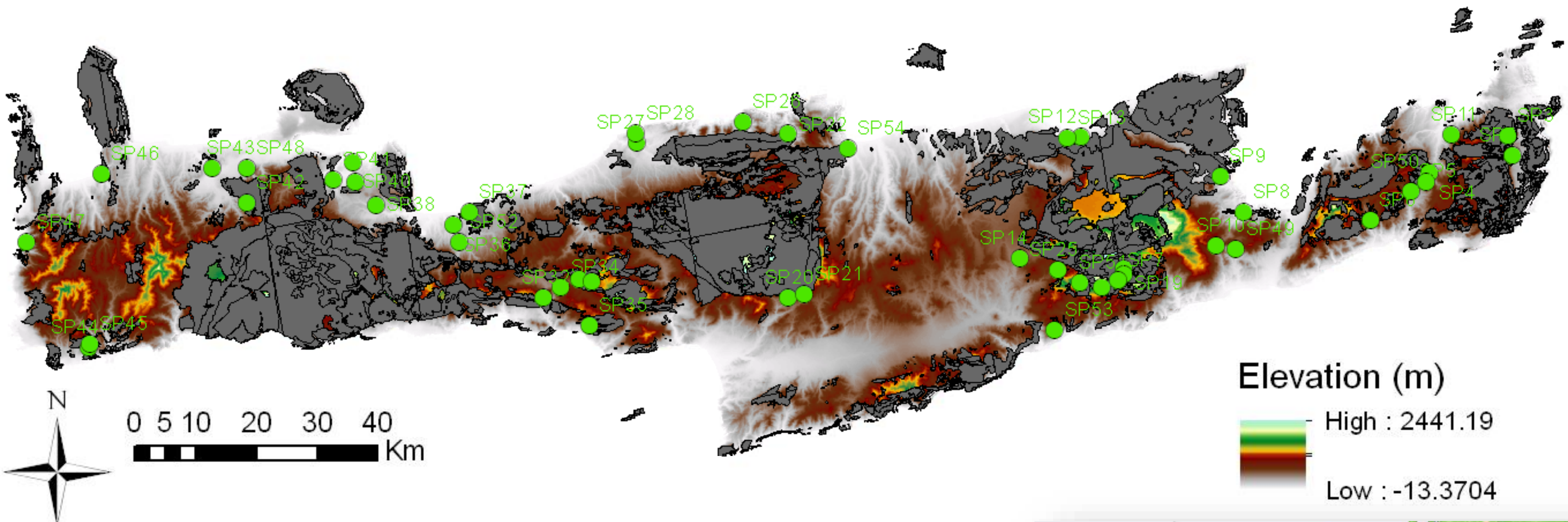


PERC: percolation
GW_RCHRG: the shallow aquifer richarge
DA_RCHRG: the deep aquifer richarge
GWQ1: baseflow from shallow aquifer
GWQ2: baseflow from deep aquifer
SURQ: Surface Runoff

PERC: percolation
SURQ: Surface Runoff
TLOSS: tributary stream losses
TWLWET: losses from the bed of wetlands
DA_RCHRG: amount of direct recharge of deep aquifer from several sub-basins;
$Q_{in,1}$:deep groudwater flow from deep aquifer to Upper Reservoir
Q_1: outlet of Upper Reservoir
Q_2: outlet of Lower Reservoir
a_1: fraction of DA_RCHRG to the Upper Reservoir
a_2: fraction of flow from Upper to Lower Reservoir


SETUP model
Watershed/reach delineation, Landcover and landuse attribution, soils distribution and types, climate data (pcp, tmp, userwgn)
SWAT MODEL
No Karst Subbasins
Karst Subbasins
Adapted SWAT Model
- Karst Soils/GW par.
-wetlands
-stream losses from tributaries
Water consumption analysis and abstractions in each subbasin
ANALYSIS OF PLANT GROWTH
CALIBRATION of selected subbasins
SWAT-CUP SUFI-2
REGIONALIZATION of calibrated parameters
CALIBRATION of SPRINGS
Karst-flow model
Add SPRINGS as POINT SOURCES in SWAT

The case study: Crete Island

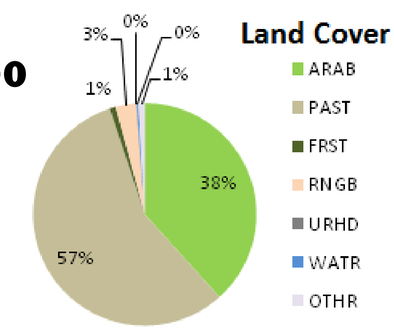


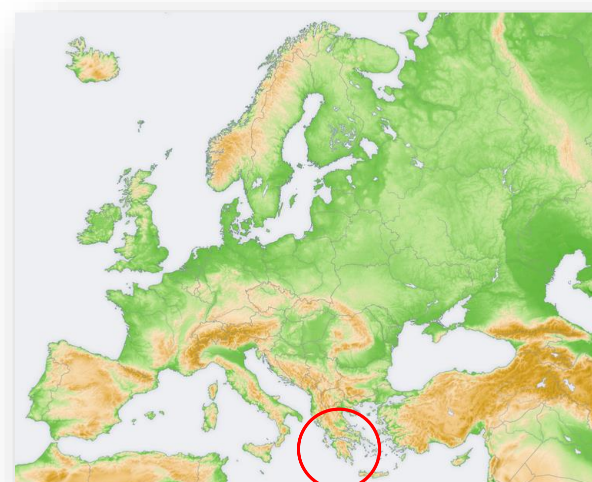
Total area 8336 km^2

30% of Carbonate Rocks (~ 3000 km^2), 47 monitored Springs

2550 km^2 of agricultural land, 1200 km^2 irrigated area

~ 360 Mm^3/y demand for irrigation





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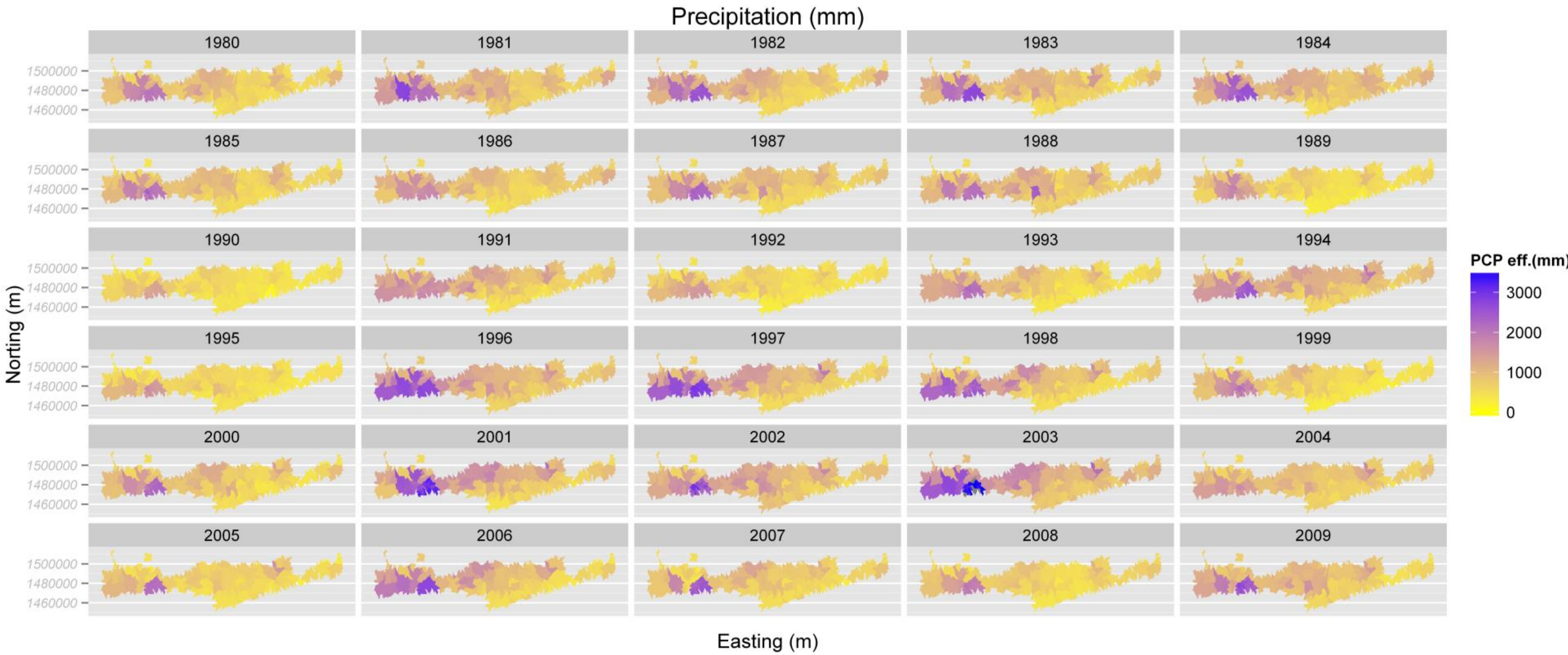

Dry semi-humid Mediterranean climate

Mean annual rainfall decreases from west to east

Mean Annual temperature 18.5° in the West and 20° and the South decreasing with altitude

In the model: 69 stations with daily data for precipitation and 21 stations for temperature (period 1961-2009)

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▲ **22 gauged streamflow stations**
● **47 gauged springs**

STR: 15 for calibration and 7 for validation, monthly calibration, period 1980-2009 (before warm up 10 years)

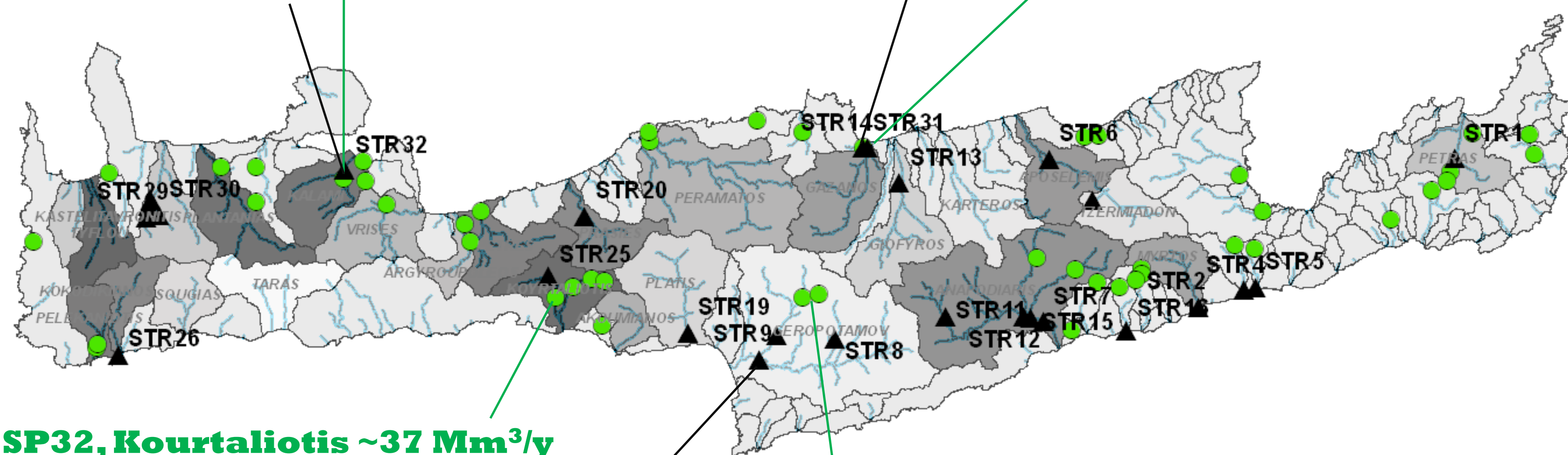
SP: daily calibration from 1983-2009

SP1, Almiros ~ 240 Mm³/y

STR31, AlmirosH ~240 Mm³/y

SP41, Platanos ~82 Mm³/y

STR32, Koiliaris 180 Mm³/y



SP32, Kourtaliotis ~37 Mm³/y

STR9, Geropotamos ~17 Mm³/y

SP20, Votomos-Zaros ~3 Mm³/y
SP21, Gergeri ~1.5 Mm³/y

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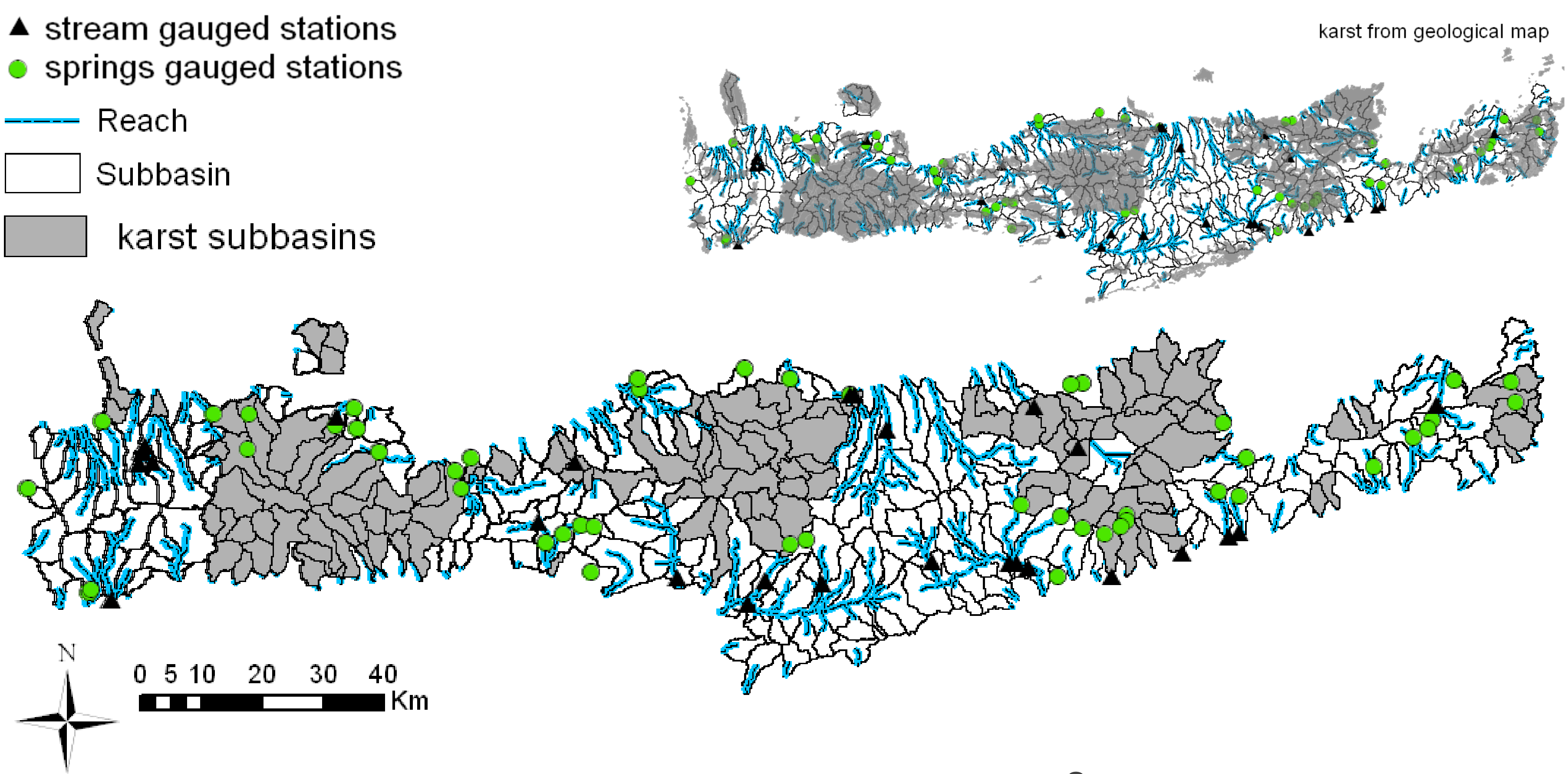
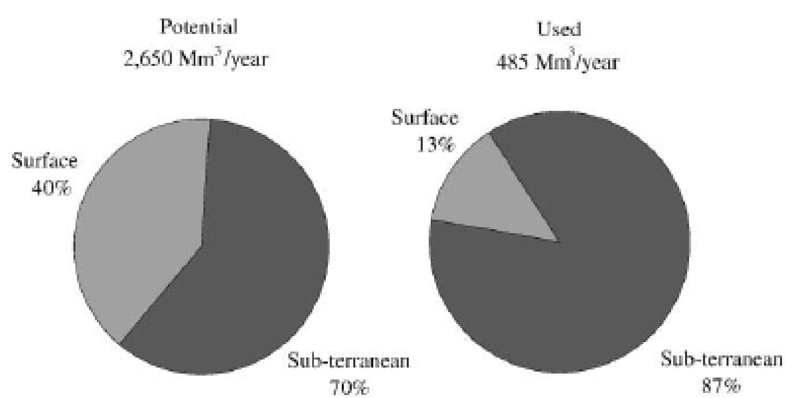


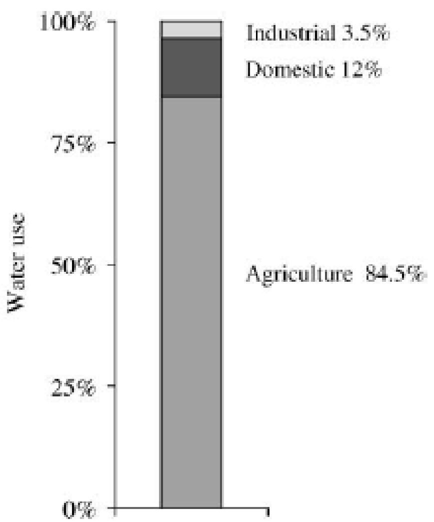
352 subbasins, 19 km² avg area
502 HRUs
2600 km² total area karst-subbasins

Land cover was derived from a 1 km raster (CAPRI -SAGE -HYDE -GLC2000) for the year 2005.

Land use was obtained from the Agriculture statistics of Greece, 2005 and distributed using an Optimization Tool.

The major water use in Crete is irrigation for agriculture (84.5% of the total consumption) while domestic use is 12% and other uses 3.5%. The monthly abstractions from domestic, industry and other uses were modeled using the file .WUS, instead the abstractions for irrigation were defined in .MGT2.





Chartzoulakis, 2001

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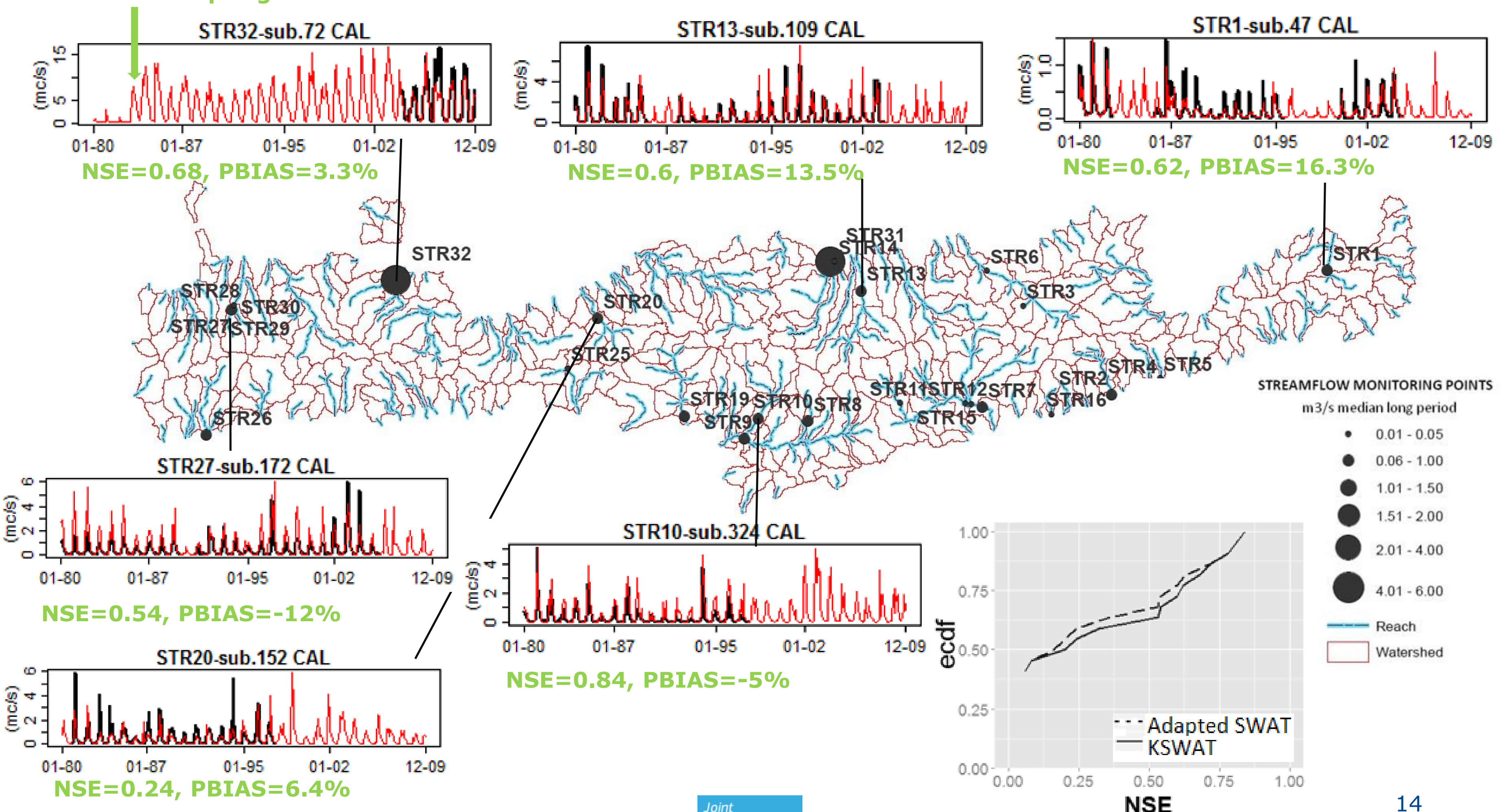
Results

Monthly simulated and observed streamflow

obs
sim

Start springs time series in SWAT



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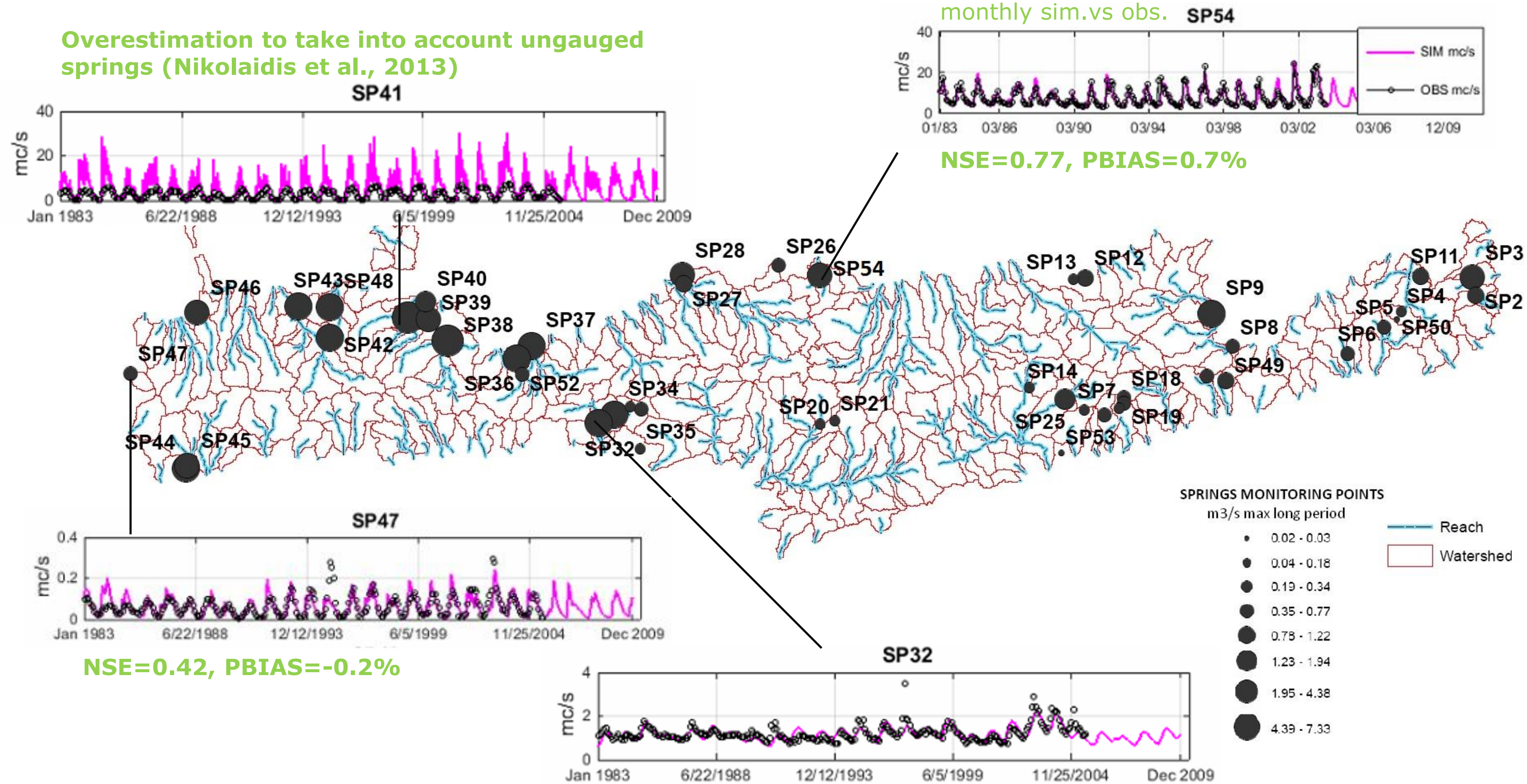
Results

Daily simulated and observed discharge of springs



Overestimation to take into account ungauged springs (Nikolaidis et al., 2013)

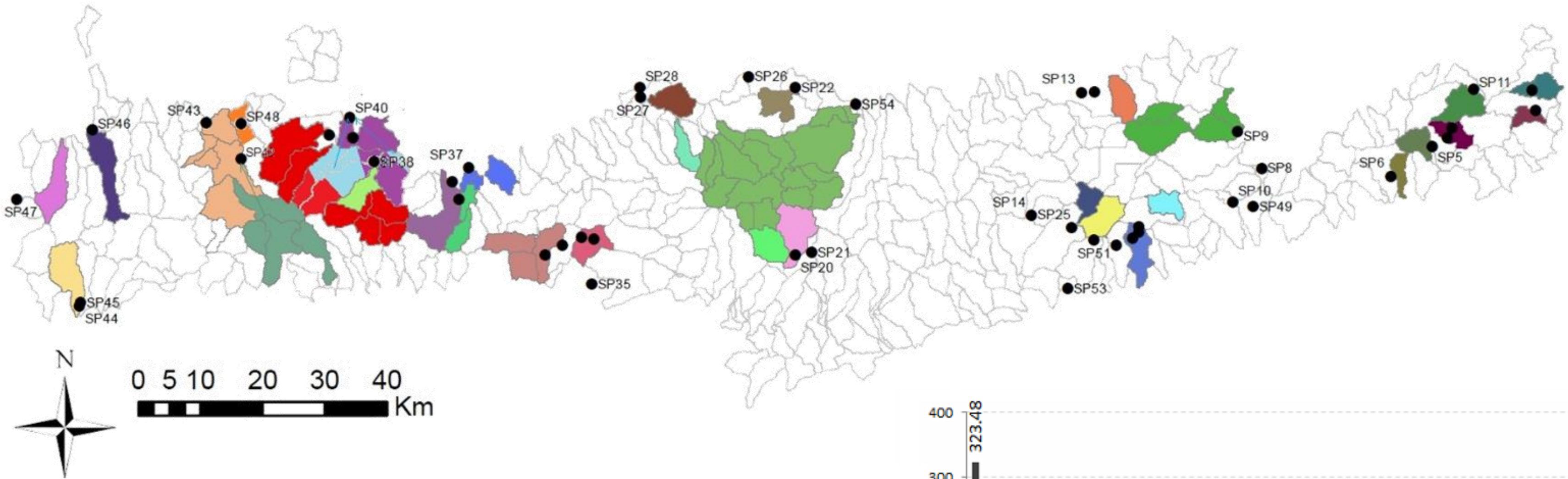
NSE=0.77, PBIAS=0.7%

NSE=0.42, PBIAS=-0.2%

NSE=0.44, PBIAS=-0.8%

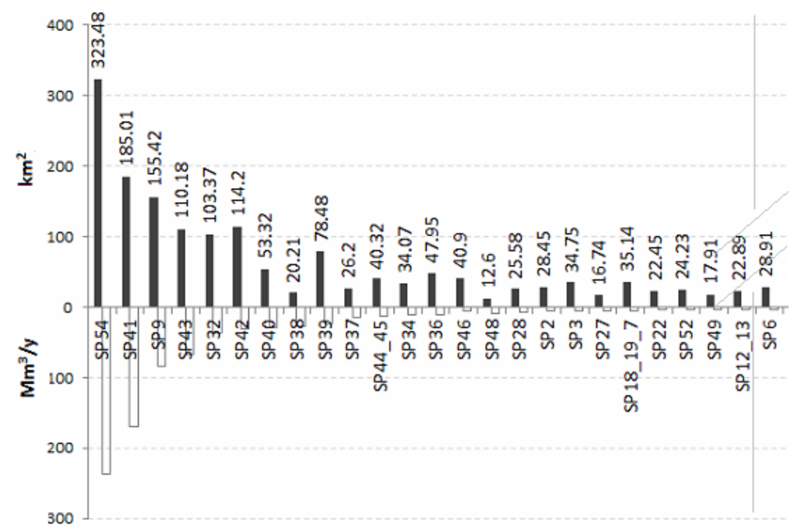
Discussion

EXTENDED KARST AREAS



The extended karst area of each spring was defined

The main extended karst area drains ~ 300 km² into Almiros Springs (SP54) that discharges directly ~240 Mm³/y to the sea



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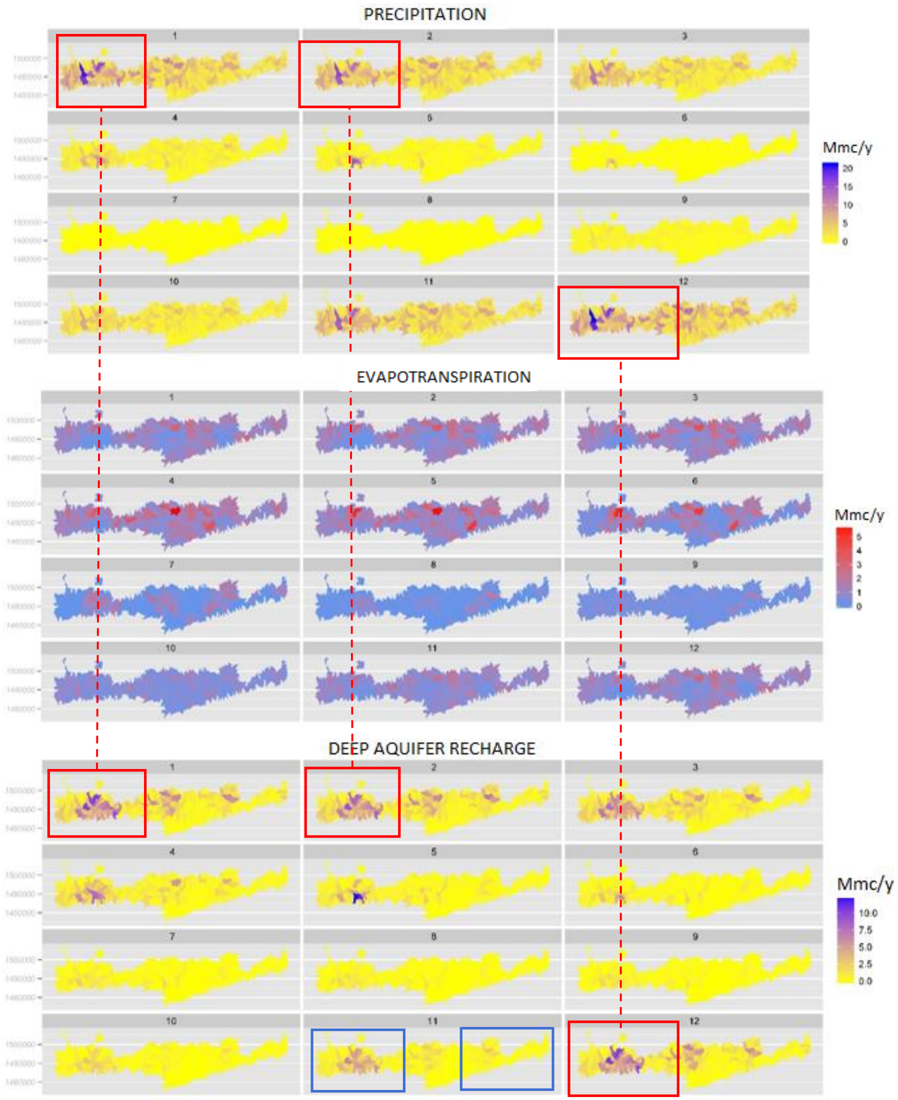
Discussion

THE SPATIAL and TEMPORAL DISTRIBUTION OF RESOURCES



Long term simulated monthly variation of precipitation, evapotraspiration and water resources in deep aquifer in each subbasin

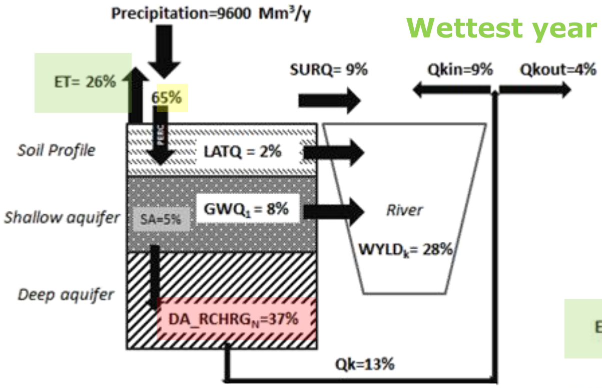
Direct connection of precipitation and aquifer in karst subbasin

Clear regional and seasonal variation in water availability in the aquifer:surplus in the west, deficit in the east

Discussion

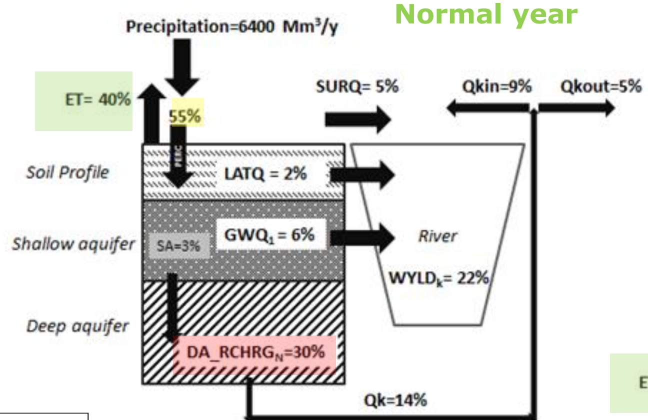
THE WATER BALANCE UNDER DIFFERENT HYDROLOGICAL CONDITIONS

Wettest year



~3500 Mm³/ y Water resources in deep aquifer

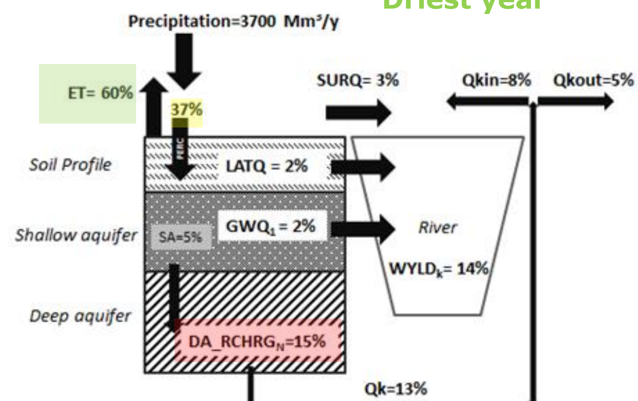
Normal year



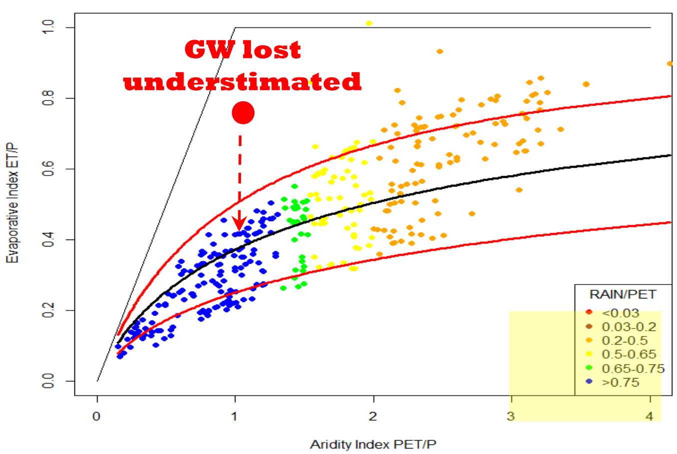
~2000 Mm³/ y Water resources in deep aquifer

The total available water resources in the deep aquifer changes significantly under different hydrological conditions

Driest year



~500 Mm³/ y Water resources in deep aquifer



unoff Q_{sur}	Infiltration I
.87 (11%)	1.25 (16%)
.39 (16%)	1.67 (19%)
.73 (13%)	0.94 (17%)

Conclusions

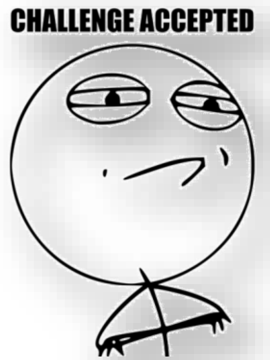
- The hybrid karst model (Adapted SWAT+ karst flow model) **has allowed to calibrate 47 springs with good efficiency and adjusting the streamflow predictions**

- **The springs contribute significantly to freshwaters** with large regional and seasonal variation. This resource **should be conserved and preserved** in particular in summer months (April-September) when available water resources are at their minimum level and the demand of agricultural and tourism is peaking. In a **WATER NEXUS** context this work highlighted the importance of addressing **trade-off solutions** on how to efficiently **allocate water in the future.**

- The water balance estimated in different hydrological conditions highlighted also the importance of preserving the resources during **climate extremes** (DROUGHT and FLOOD)

- This study described an operational methodology for the integrated water management in karst areas providing:
  - detailed hydrological balances
  - regional and seasonal accurate estimations of water availability
  - a tool for optimizing water allocation of resources and management giving information on potential overexploitation

- We will apply this methodology at large scale, however with some limitations:



~180 km^2 avg area of subbasins

Lack of information about springs position and time series

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Thank you for your attention

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References for figures in this presentation:

-slide 4:
http://web.env.auckland.ac.nz/our_research/karst/
https://simple.wikipedia.org/wiki/Karst

-slide 5:karst features
http://www.esi.utexas.edu/outreach/caves/karst.php