

Modeling water resources in Black Sea Basin

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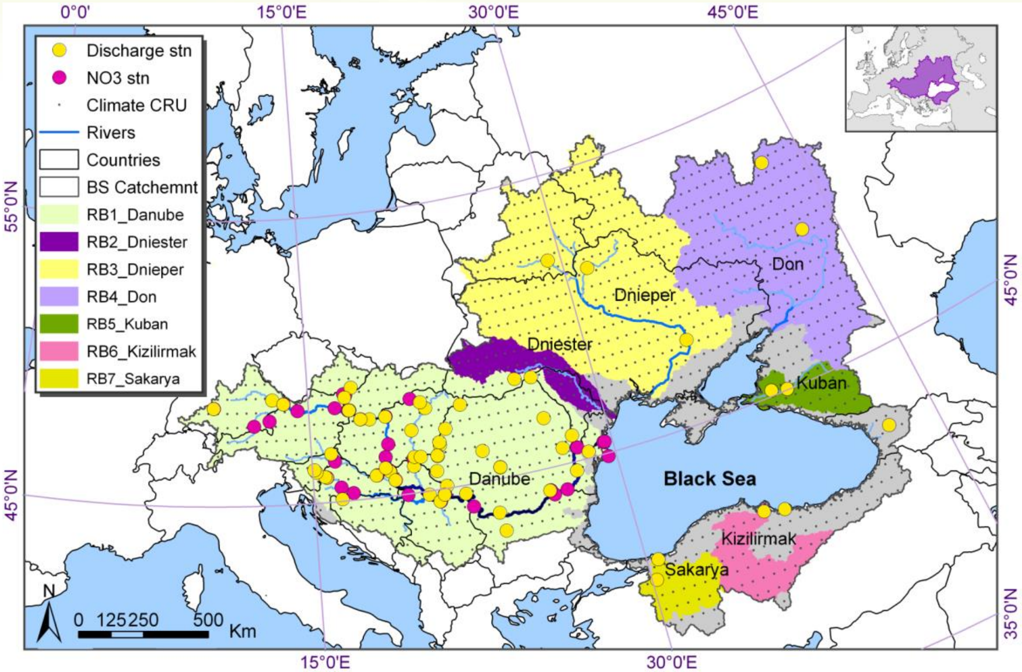
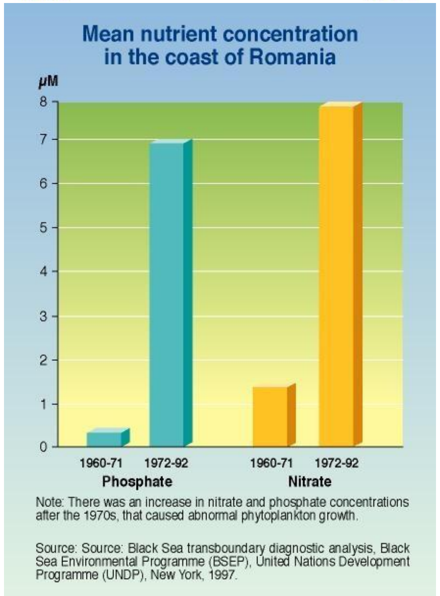
Major challenges

- Environmental degradation
- Water quality
- Water stresses
- Flood- droughts risks
- Transboundary effects
- High variability in precipitation and evaporative demand
- Agricultural productivity and water demands





What to do about it?

Research questions

To assess:

• Black Sea data gaps

• Water resources of BSB on a fine spatial and temporal resolution

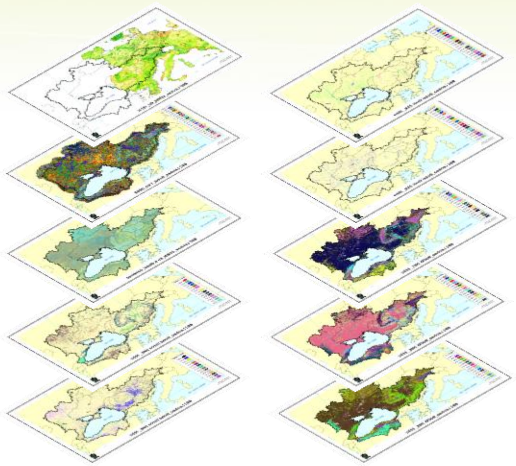
• Feasibility of running a time-consuming high-resolution hydrologic model on a PC & gridded network

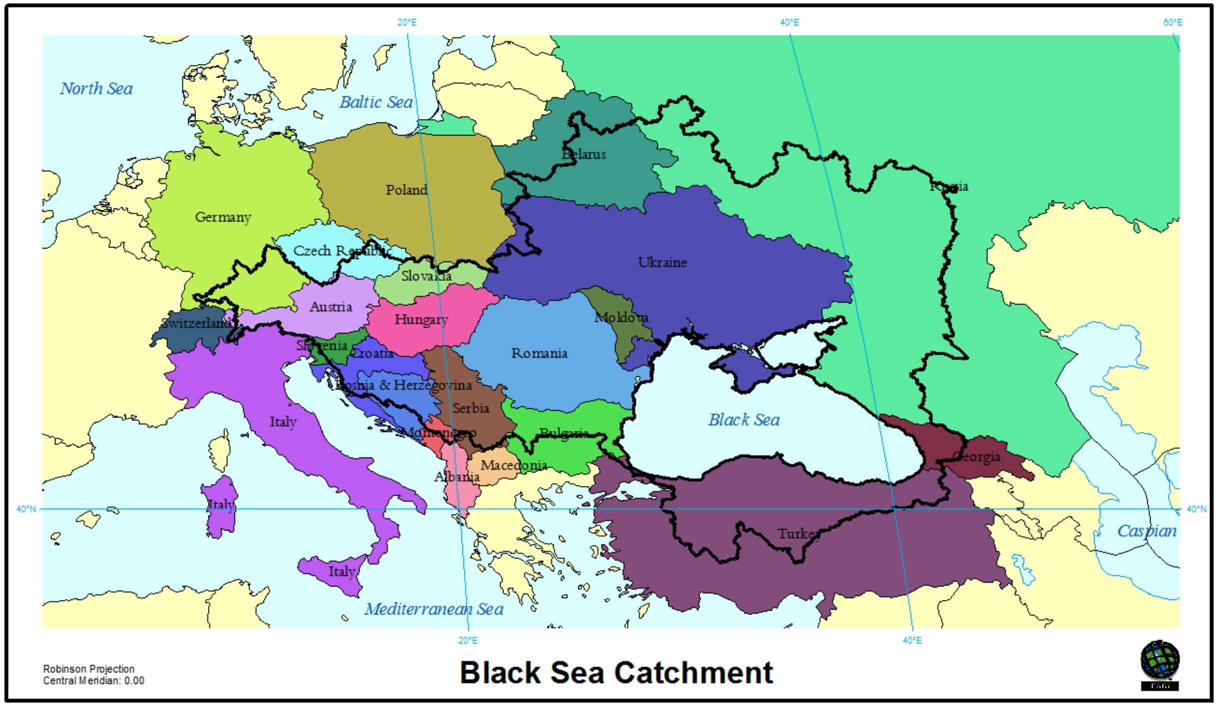
• Potential impacts of *climate change* and *landuse change* on water quantity, water quality and crop yields

Research question1:

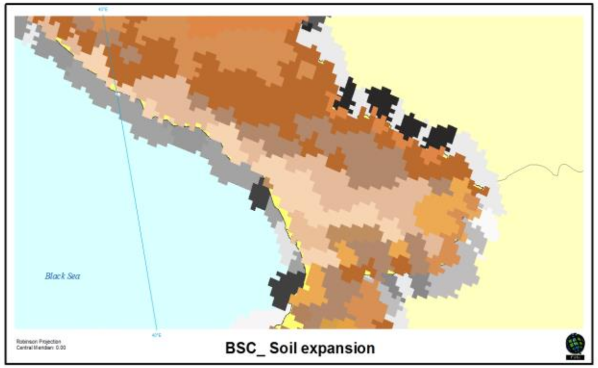
Data gaps in BSB

Data gap analysis and difficulties

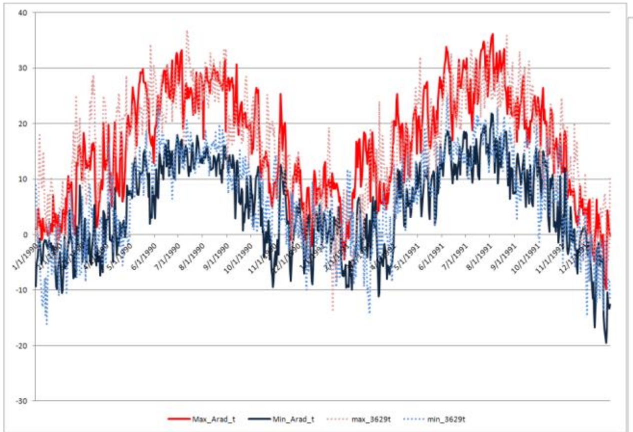


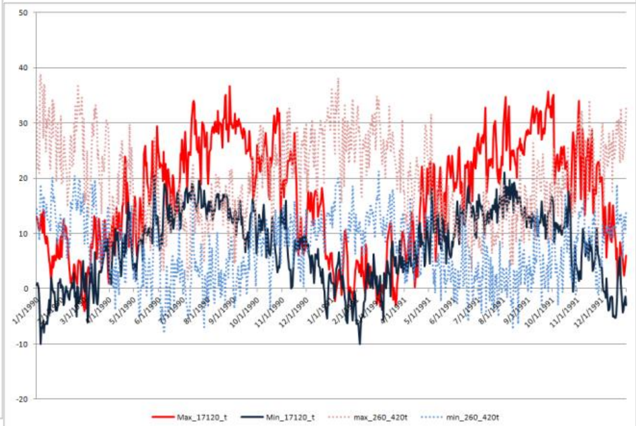


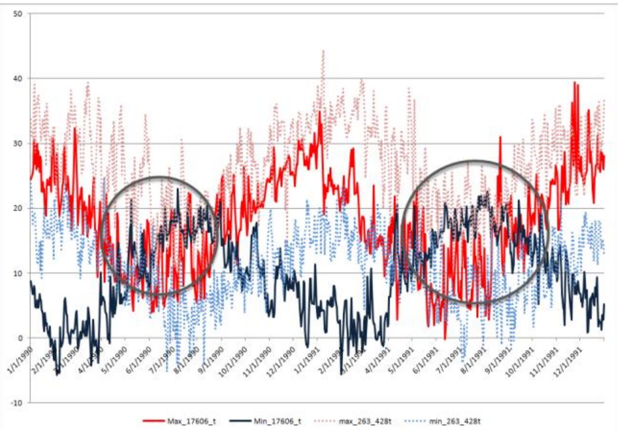
Black Sea Catchment

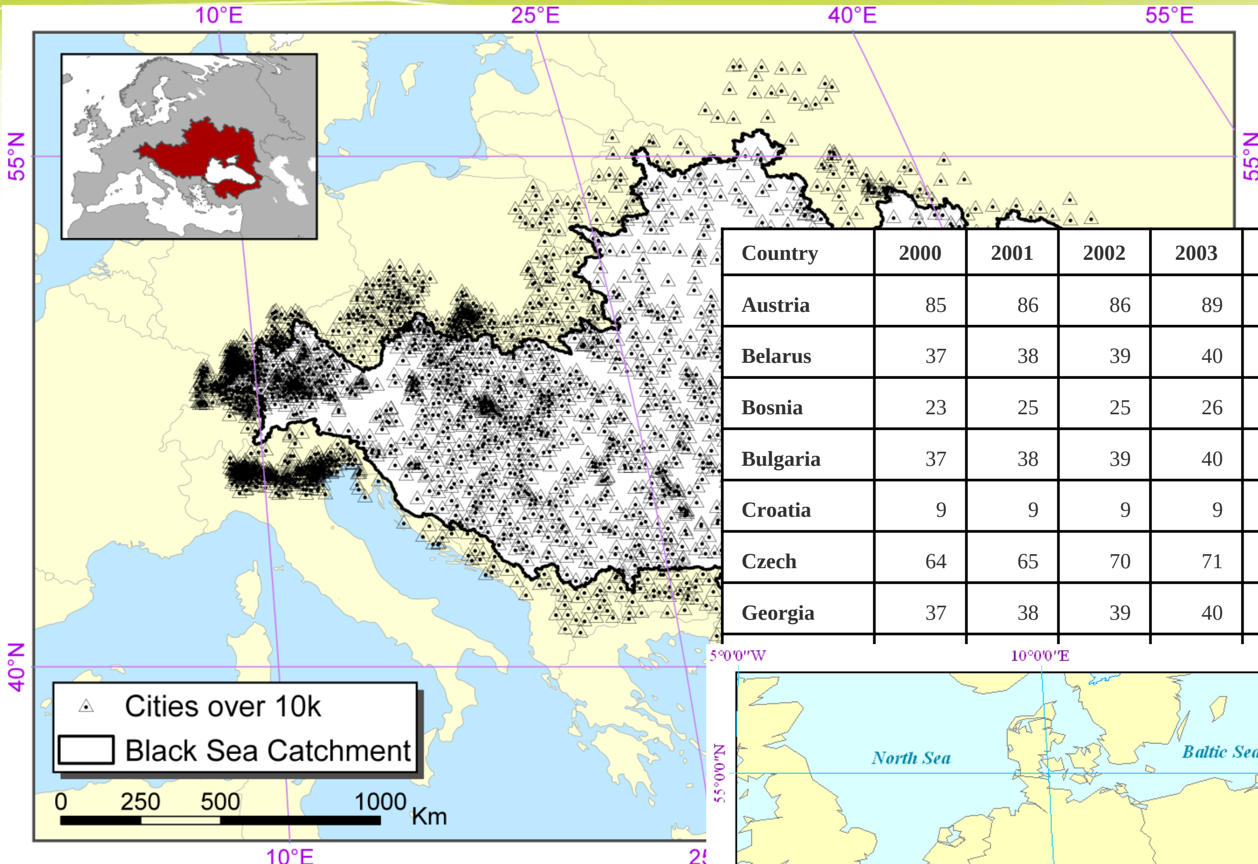


BSC_ Soil expansion

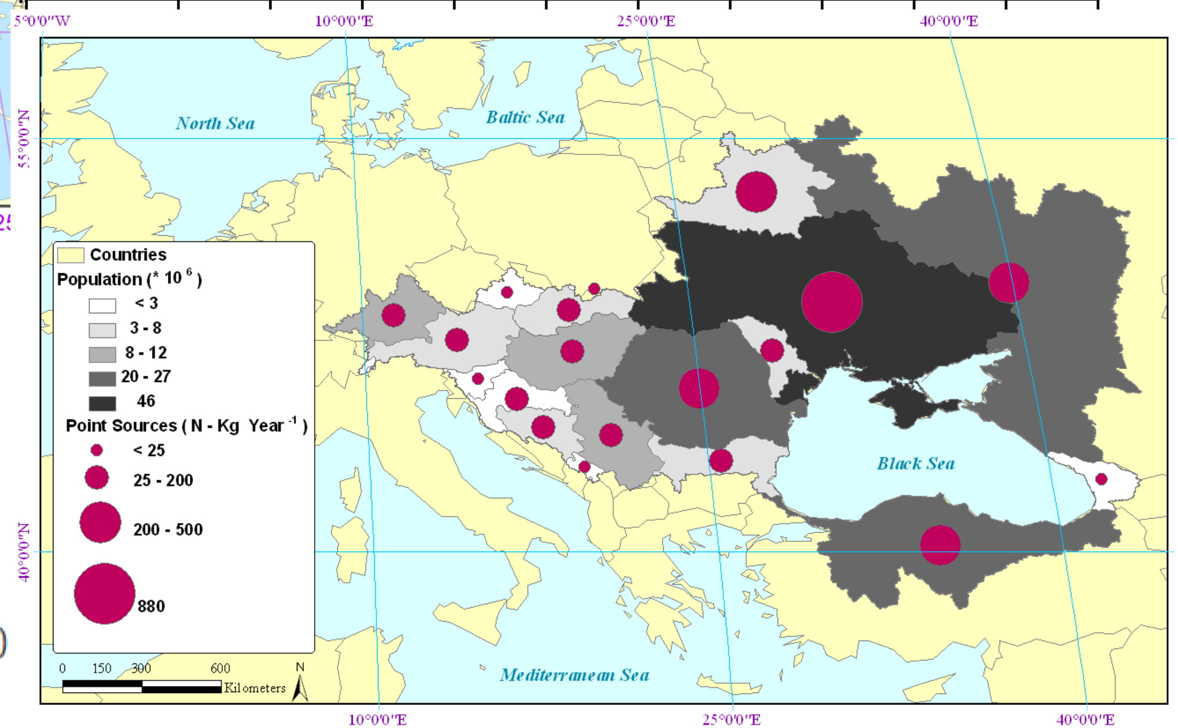








Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	85	86	86	89	89	89	92	92	93	93
Belarus	37	38	39	40	40	41	41	42	44	45
Bosnia	23	25	25	26	34	37	52	51	52	52
Bulgaria	37	38	39	40	40	41	41	42	44	45
Croatia	9	9	9	9	15	28	28	29	29	29
Czech	64	65	70	71	71	73	74	75	76	76
Georgia	37	38	39	40	40	41	41	42	44	45



Load NO3 g/day

T_{eff} = 0.8 treatment efficiency

N = 8.8 g

S_{rate} = As presented in table 2..

PE = 0.63

$$Load_{NO3} = POP_i * \left[\left(1 - S_{rate} * N / _{PE} \right) + \left((1 - T_{Eff}) \right. \right.$$

Data sets

DEM: Elevation, slope, drainage network
SRTM 90 m resolution

River network: Ecrine Rivers, 30 m resolution

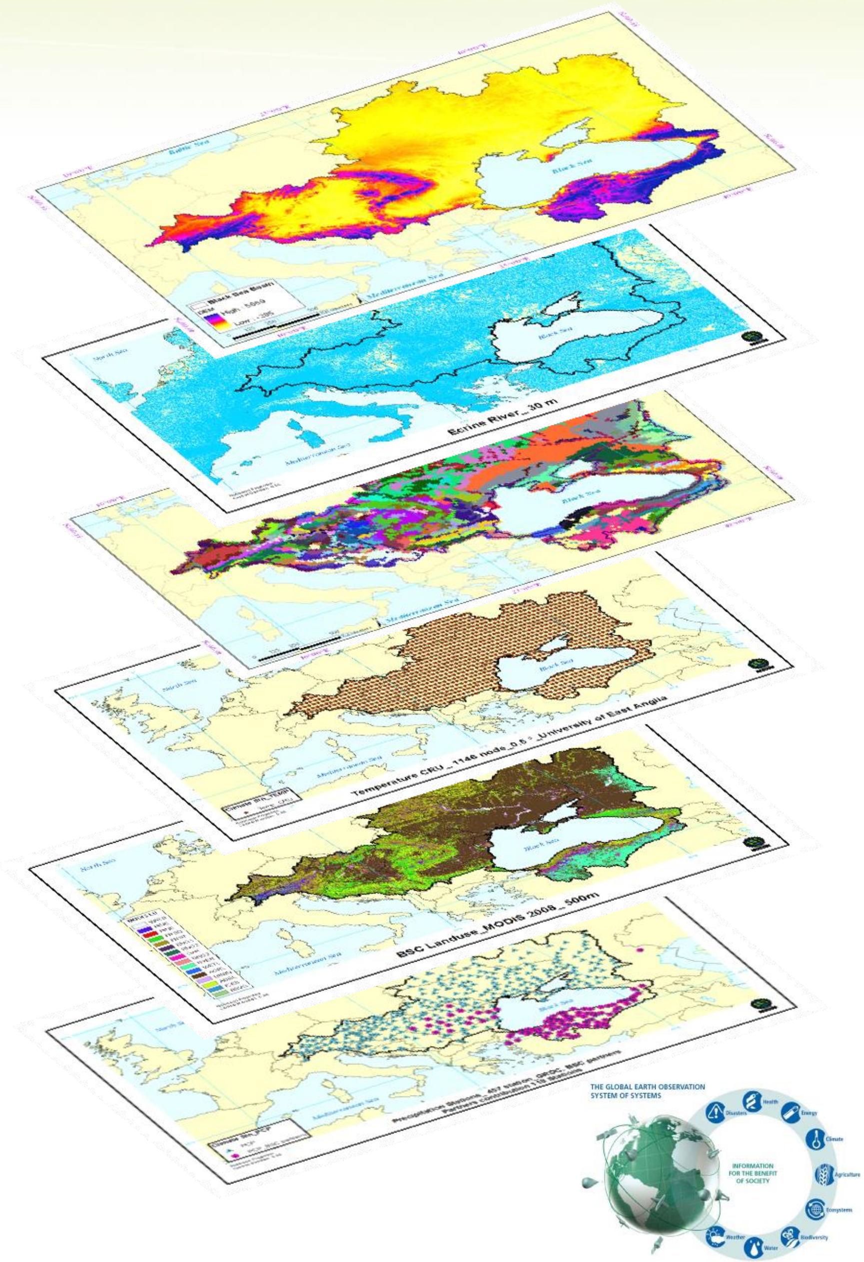
Landuse: Modis Land cover, Nasa, 500 m resolution

Soil: Hydro-pedological parameters. FAO/UNESCO, Scale: 1:500 000

Climate: Daily precipitation, temperature and solar radiation for 1973-2006, Climate Research Unit (CRU)

Agricultural Management: Crop types, Harvested area, Crop calendar, crop Yields, Miraca 2000, 5 Arc min resolution

Calibration & Evaluation: Crop yields, river discharge, NO3



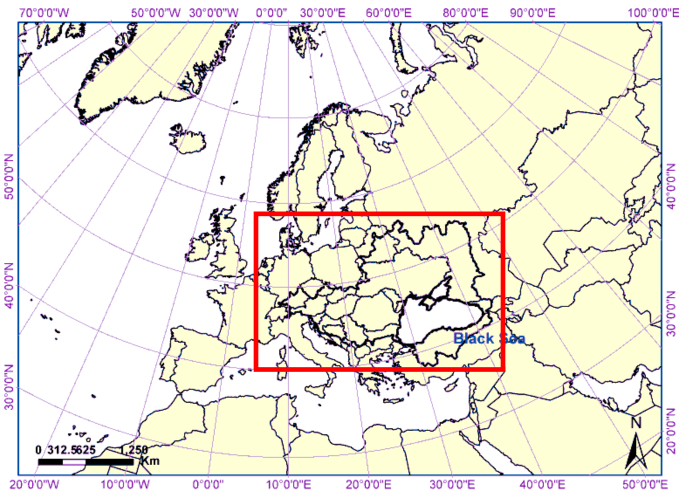
GEOSS: A Global, Coordinated, Comprehensive and Sustained System of Observing Systems

Research question2:

High resolution water resources assessment in BSB

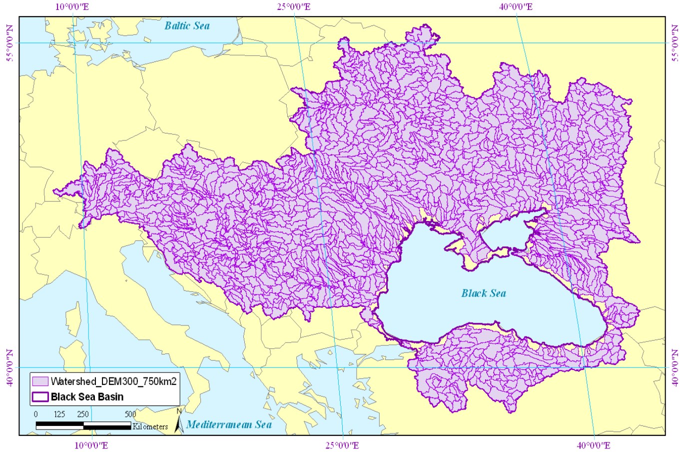
SWAT in the Black Sea Basin

Europe

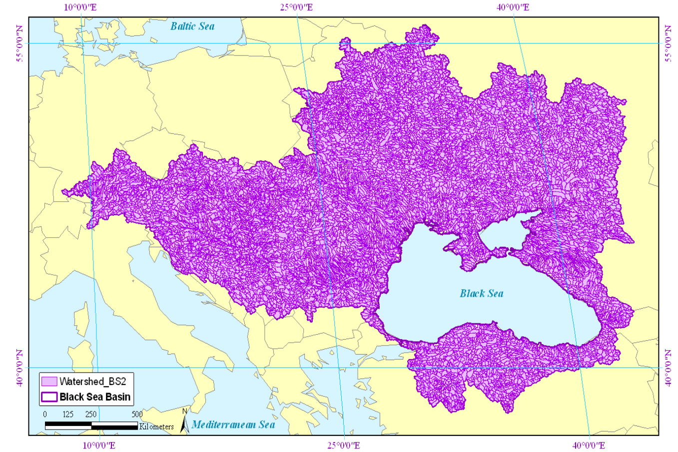


Basin

Sub- basin



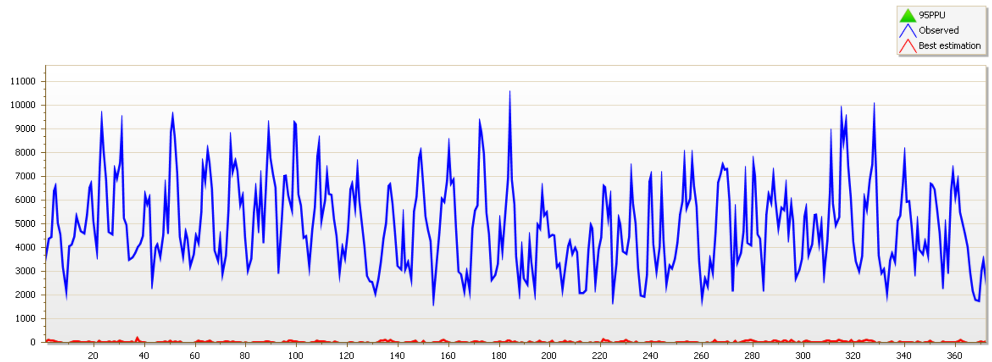
HRU

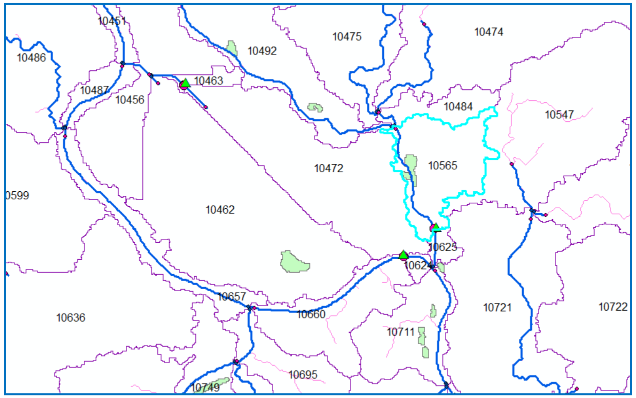


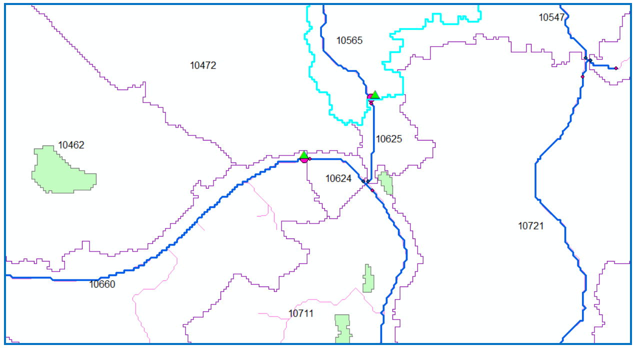
Complications

- Imprecise gauge location

q_10565







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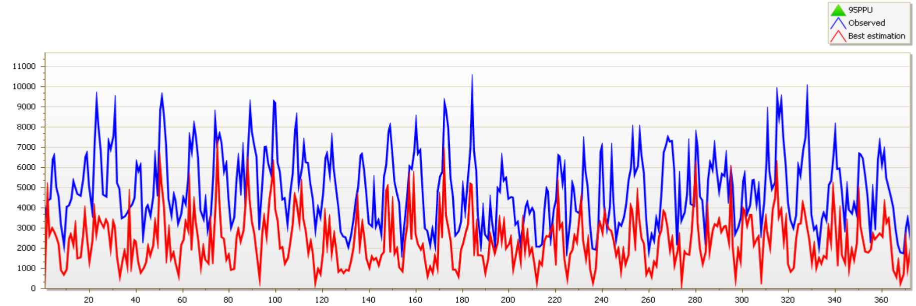
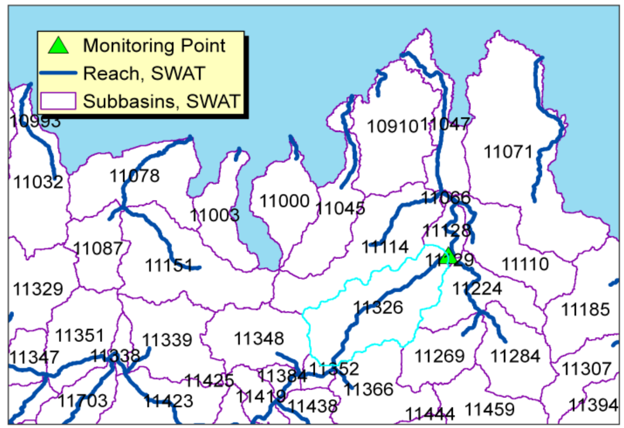
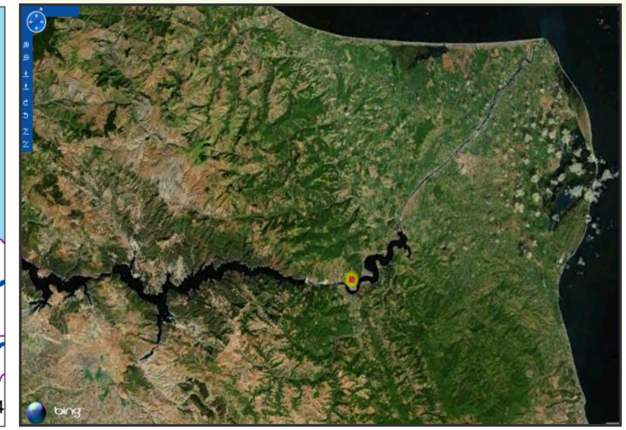


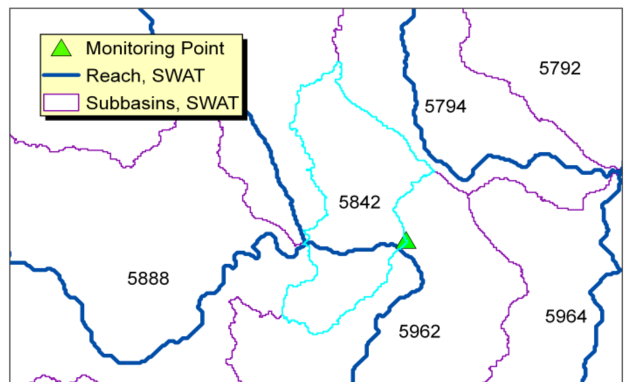
Complications

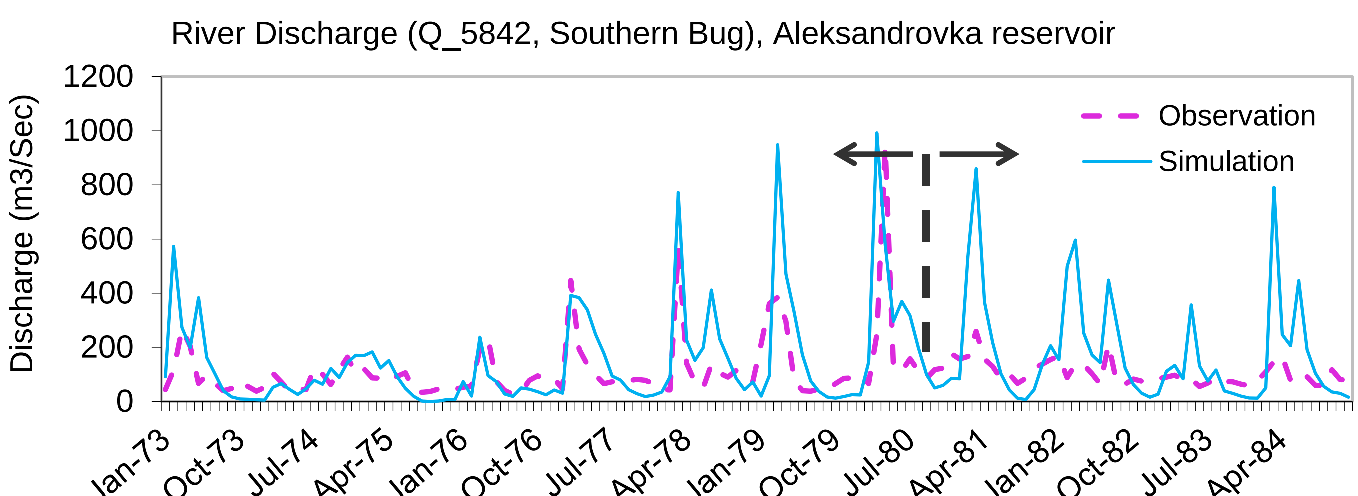
- Dams, Reservoirs

- Highly agricultural areas and water abstractions





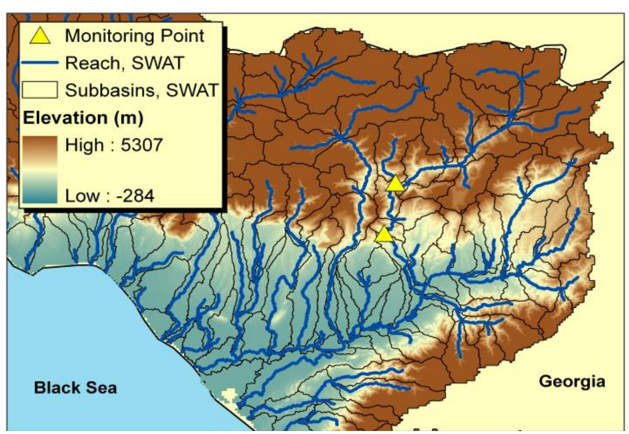


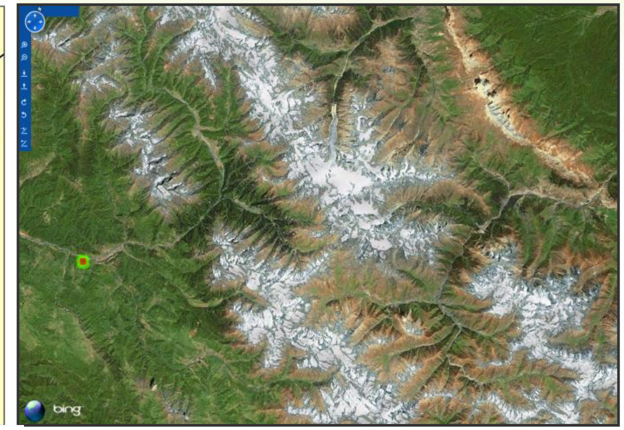


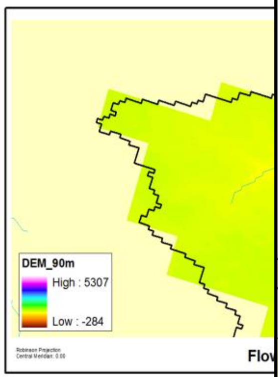
Complications

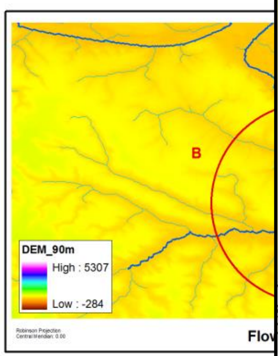
- Glaciers

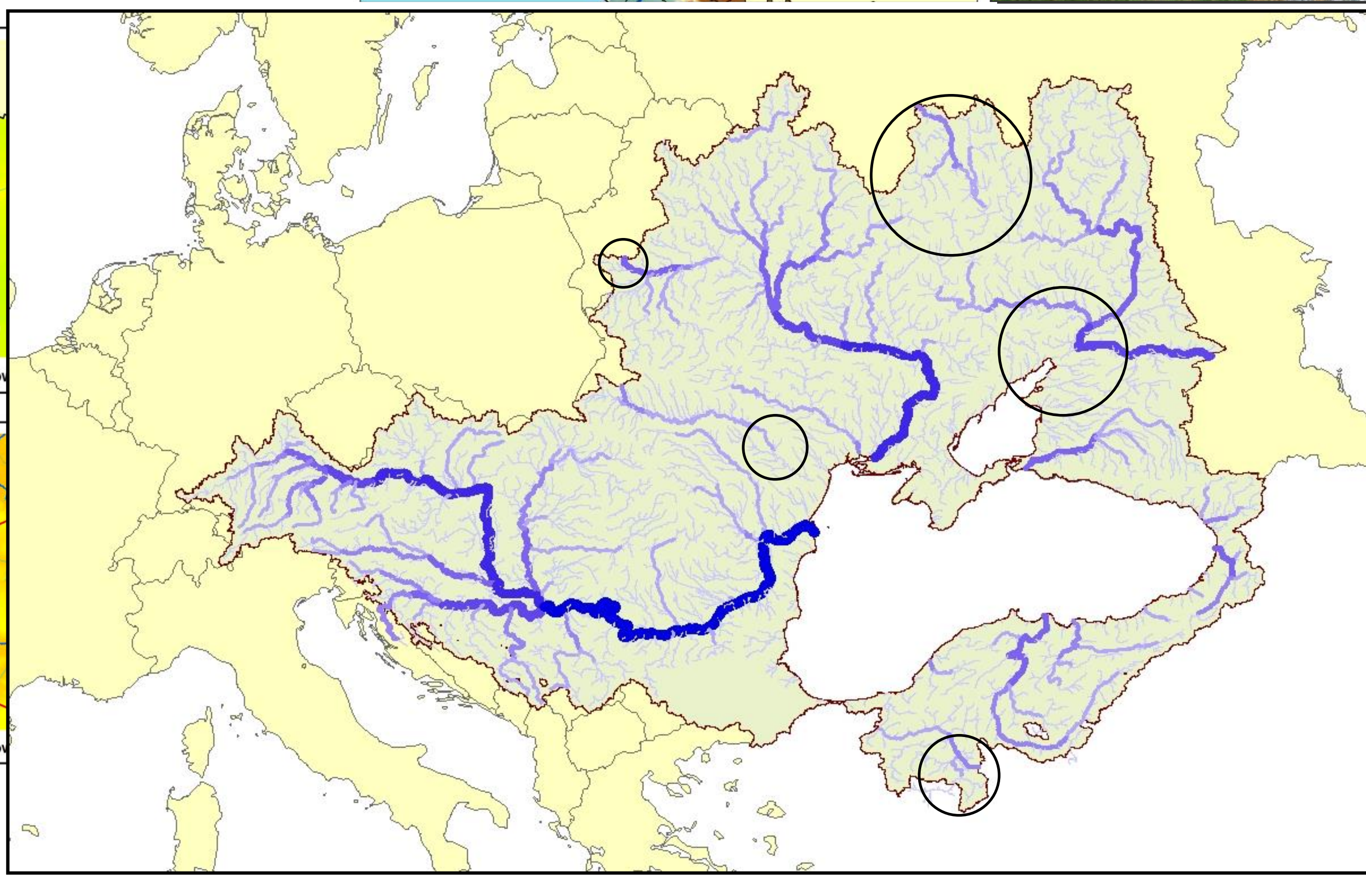
- Disconnected rivers

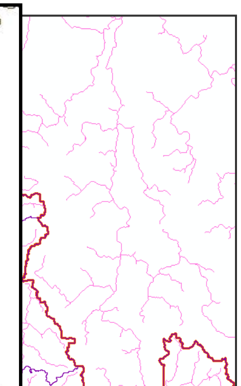




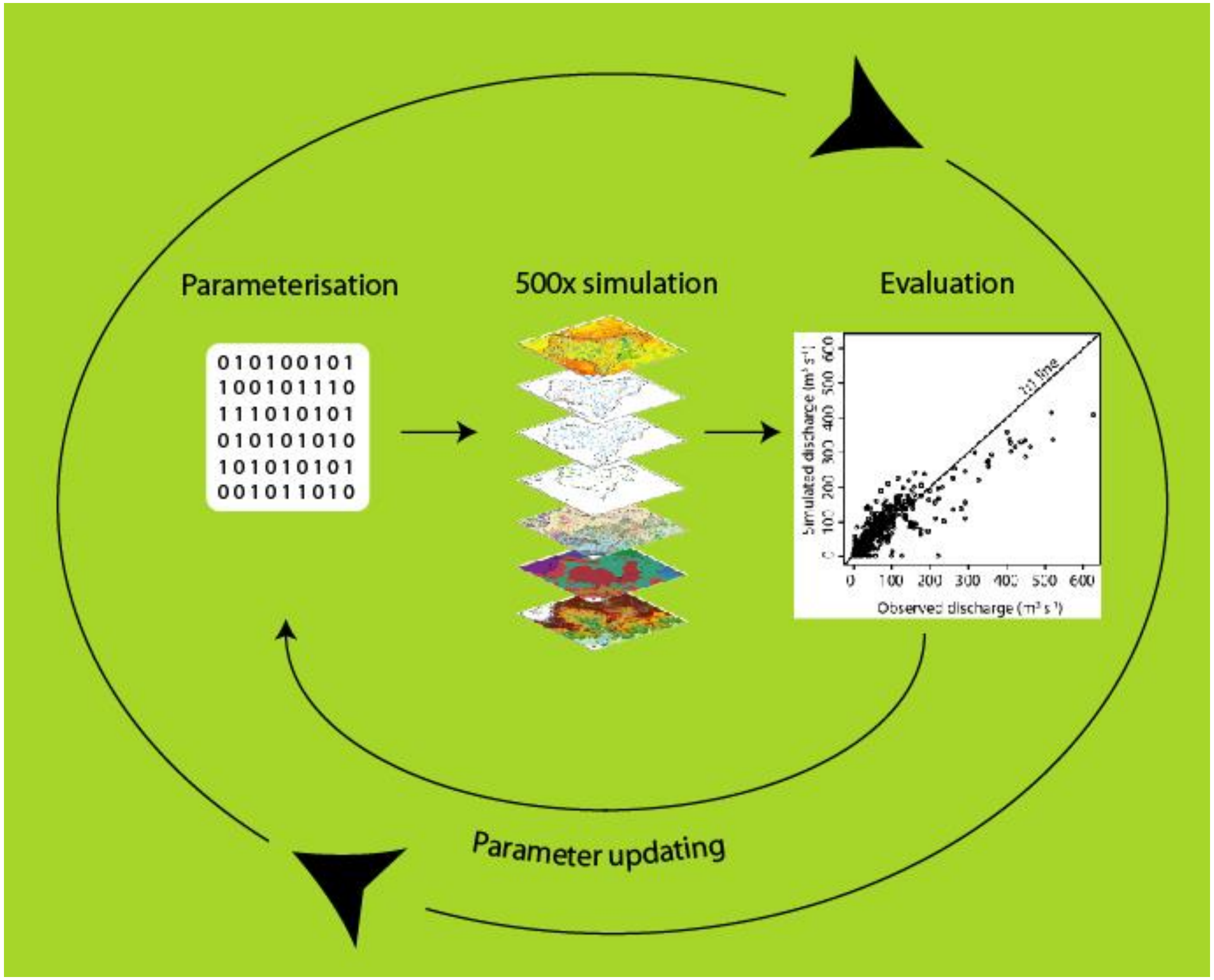


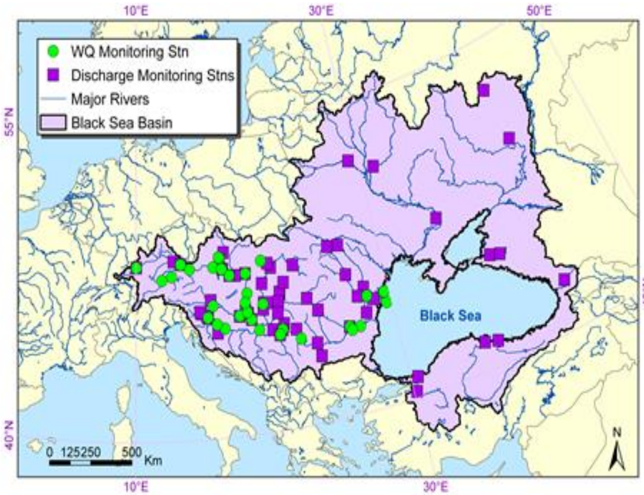






Calibration, Evaluation & Uncertainty





eawag aquatic research

Calibration, Evaluation & Uncertainty

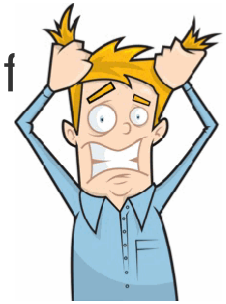
– Calibration and evaluation
  - 1973- 2000 Calibration
  - 2000- 2006 validation
  - Discharge (monthly, 79 stns)
  - NO3 (Monthly, 37 stns)

– Parameter selection based on sensitivity analysis → 26 Discharge, water quality and crop growth parameters

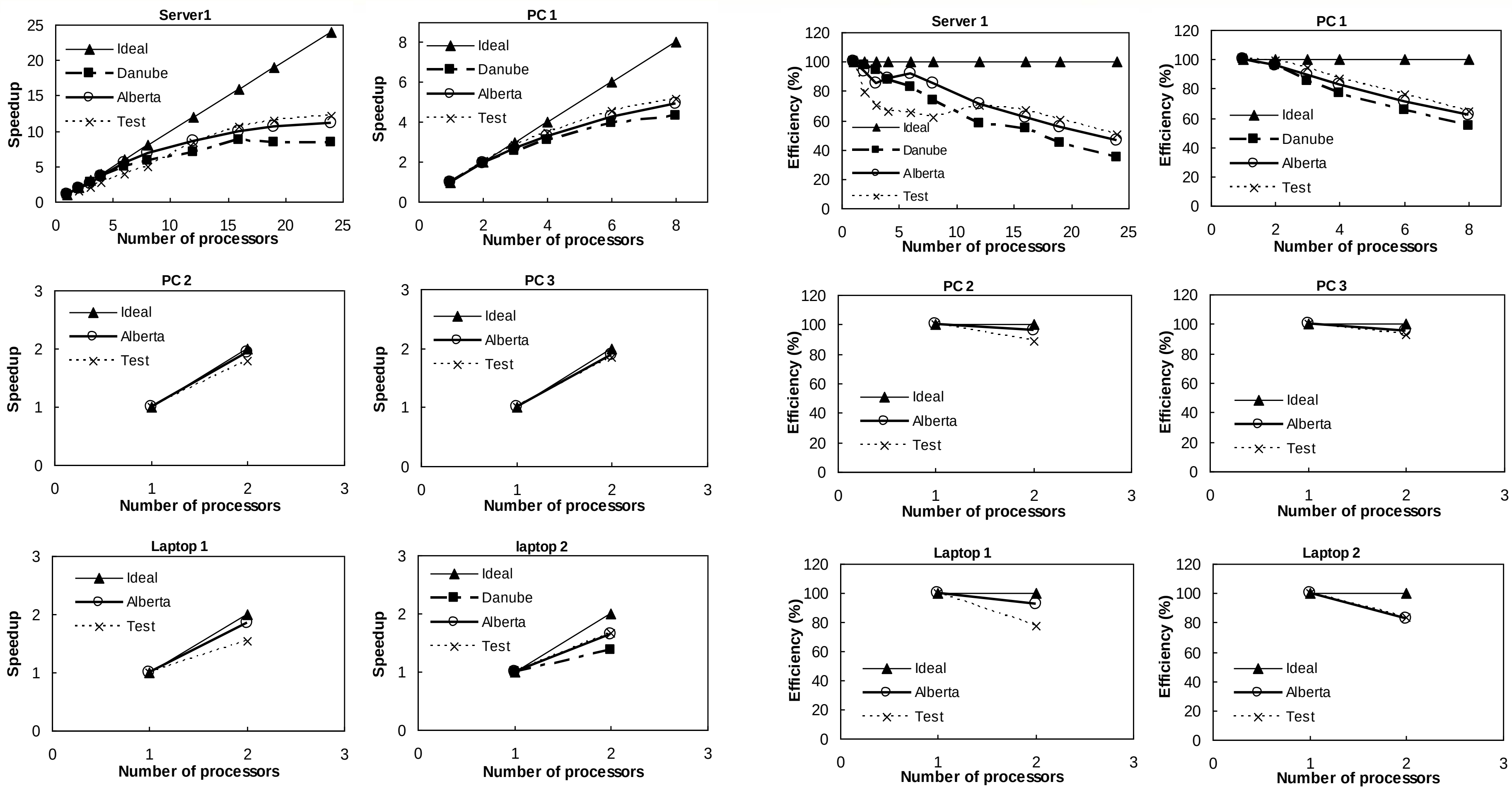
– Initial parameter ranges from physically meaningful limits at uniform probability distribution

– New ranges based on parameterisation with highest objective f

- 200 runs (Estimated run time in a single machine → **350 days!!**

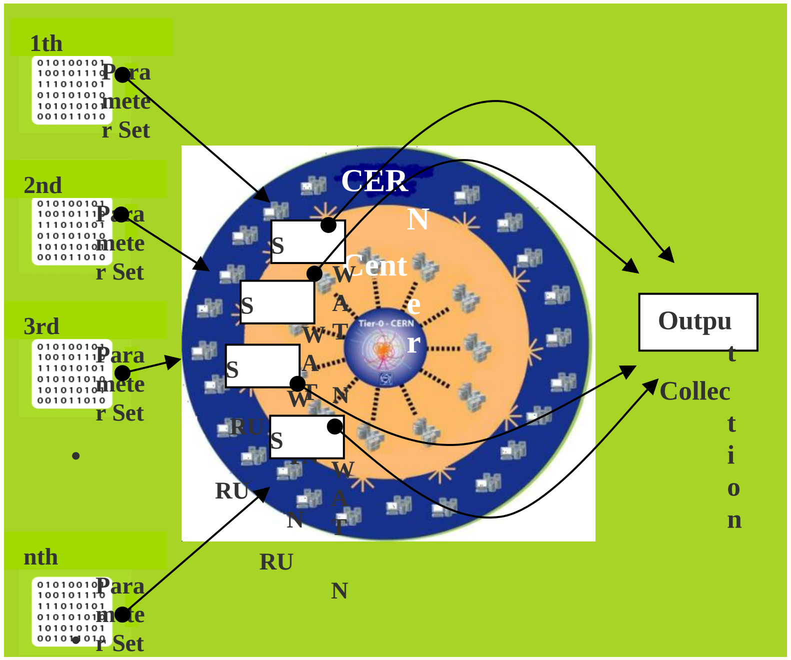


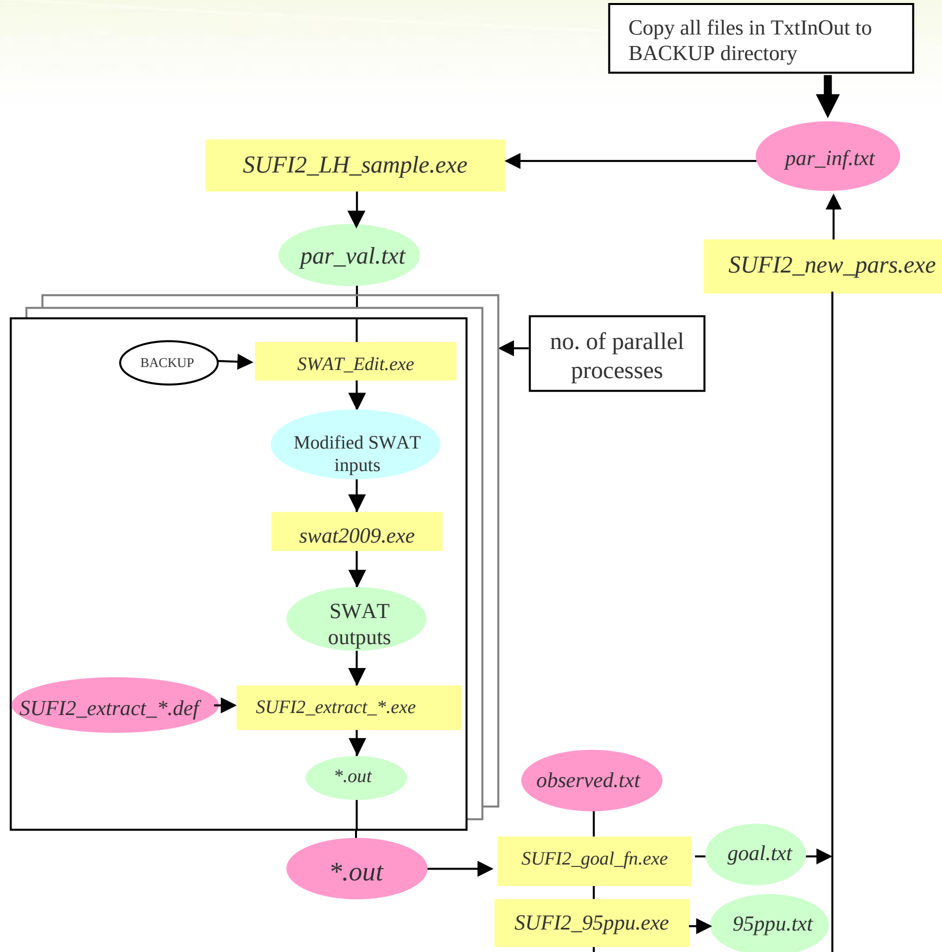
o parallel Sufi2 spead up & efficiency tested on different computers



More details:
E. Rouholahnejada, K.C. Abbaspoura, M. Vejdanib, R. Srinivasanc, R. Schulind, A. Lehmanne: A parallelization framework for calibration of hydrological models *Environmental Modelling and Software*, 2011.

Parallelization & Gridification



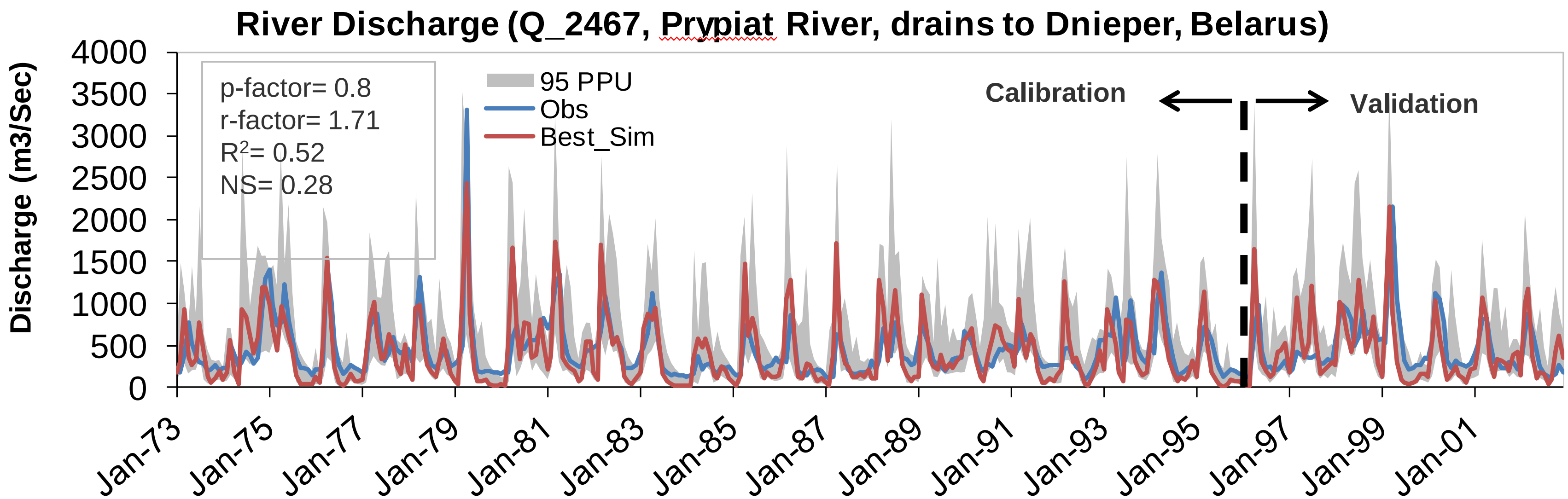


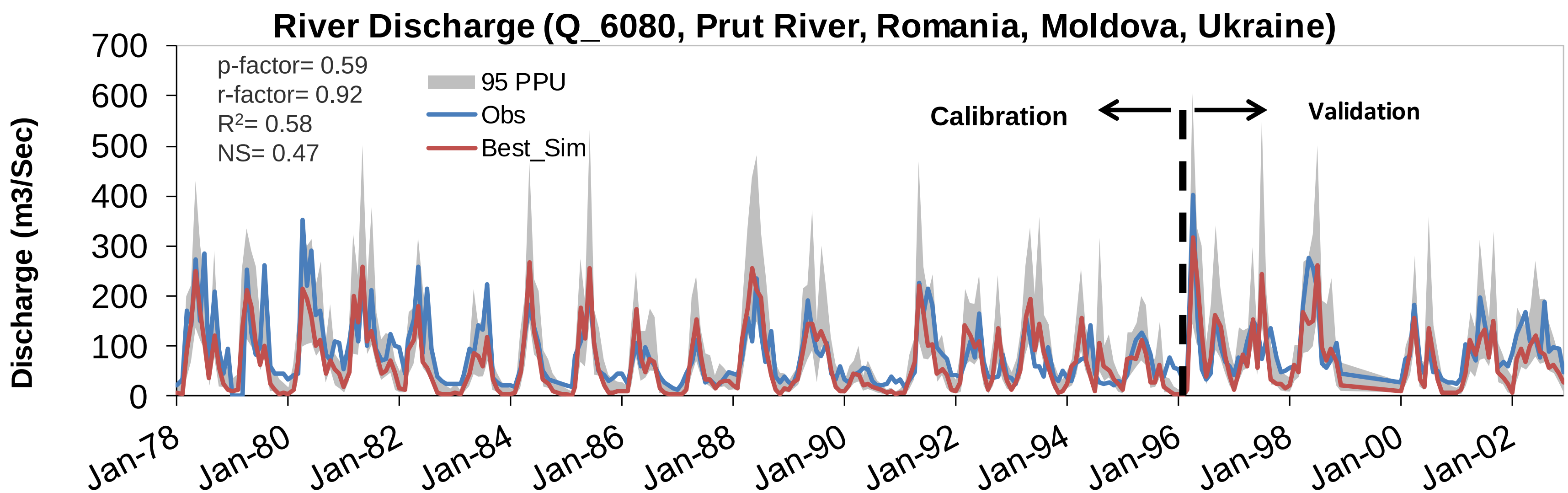
200 runs using the parallel processing and Grid infrastructure → **2 weeks!!**

(4 blocks of 50 worker node)

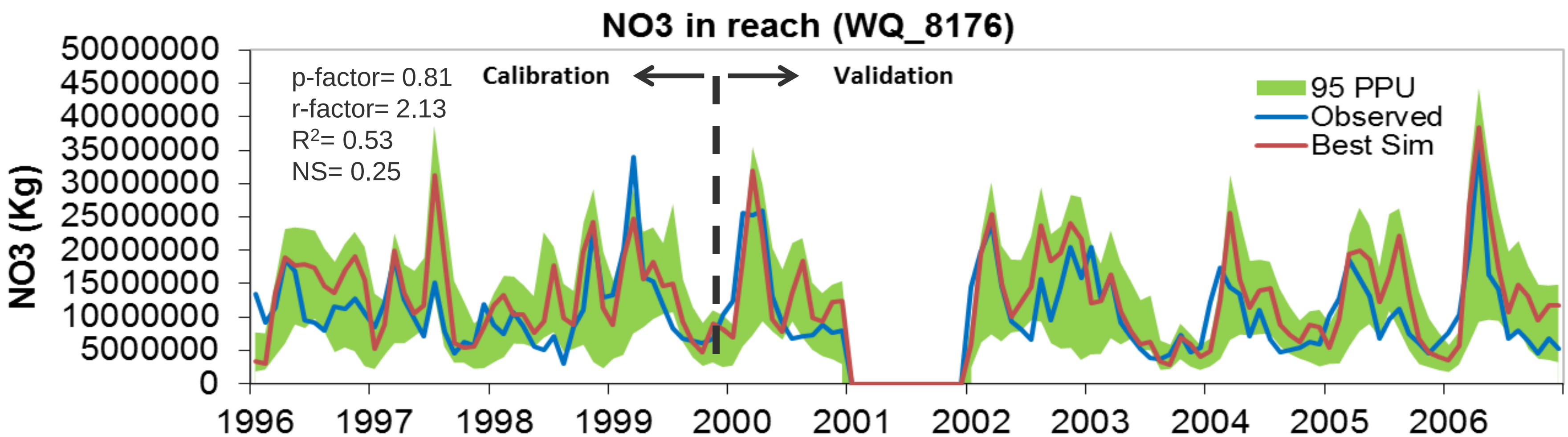
More details:
D. Gorgan, V. Bacu, D. Mihon, D. Rodila, K. Abbaspour, and E. Rouholahnejad:Grid based calibration of SWAT hydrological model (2012) NHESS.

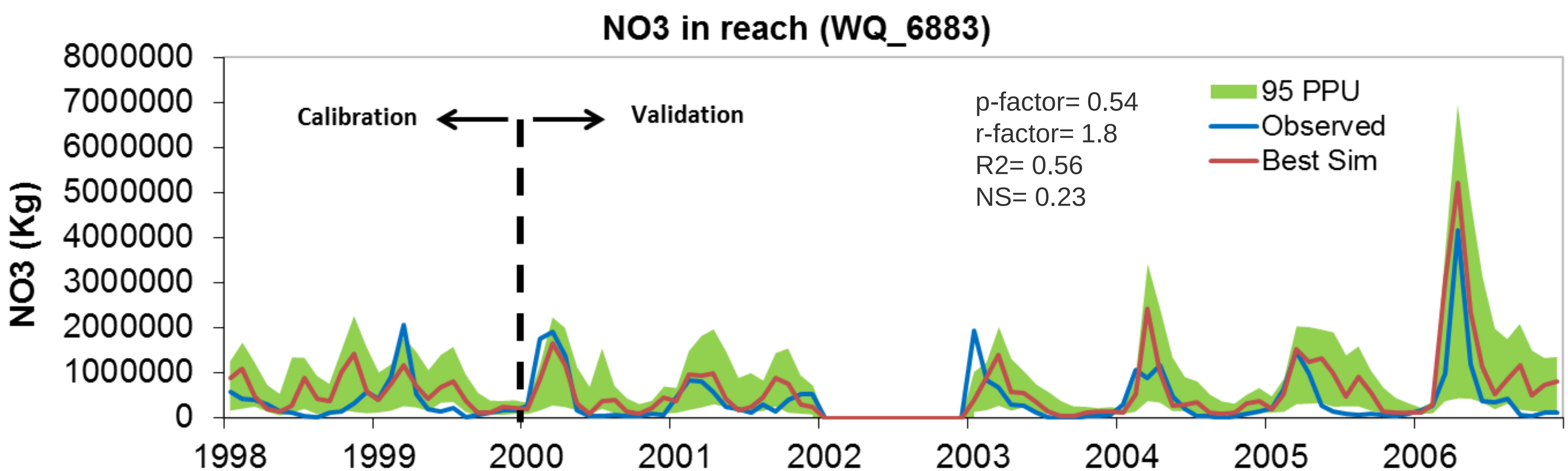
River Discharge results



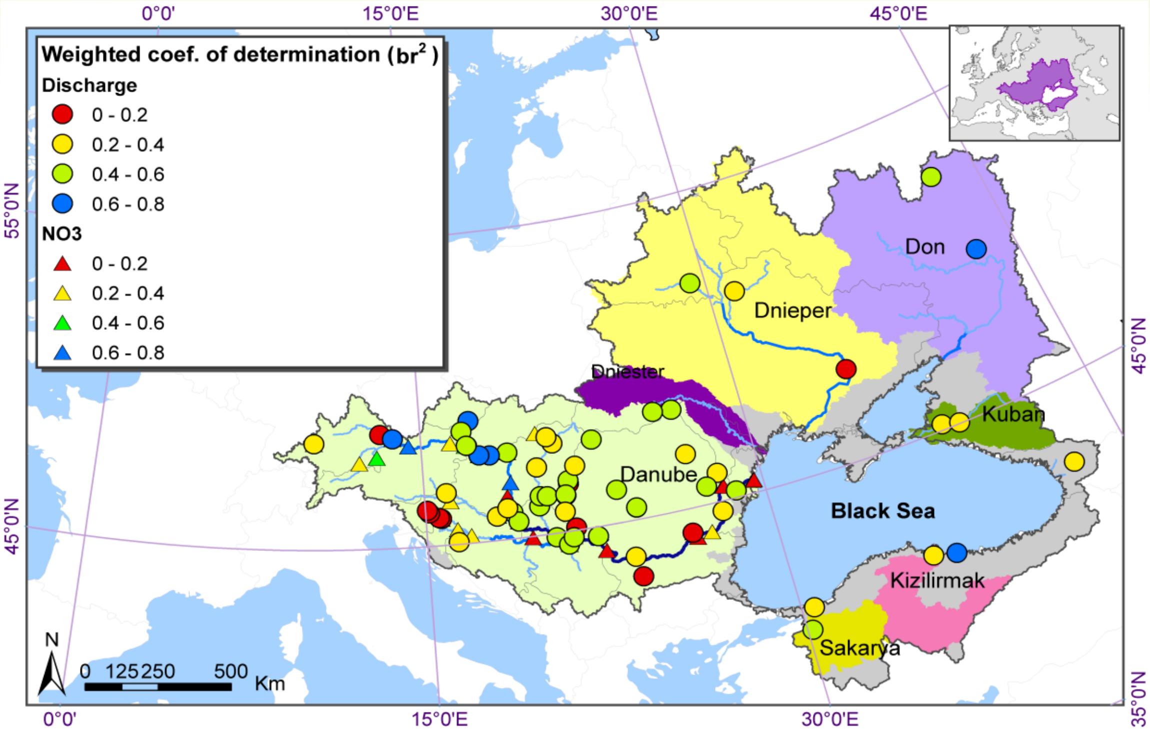


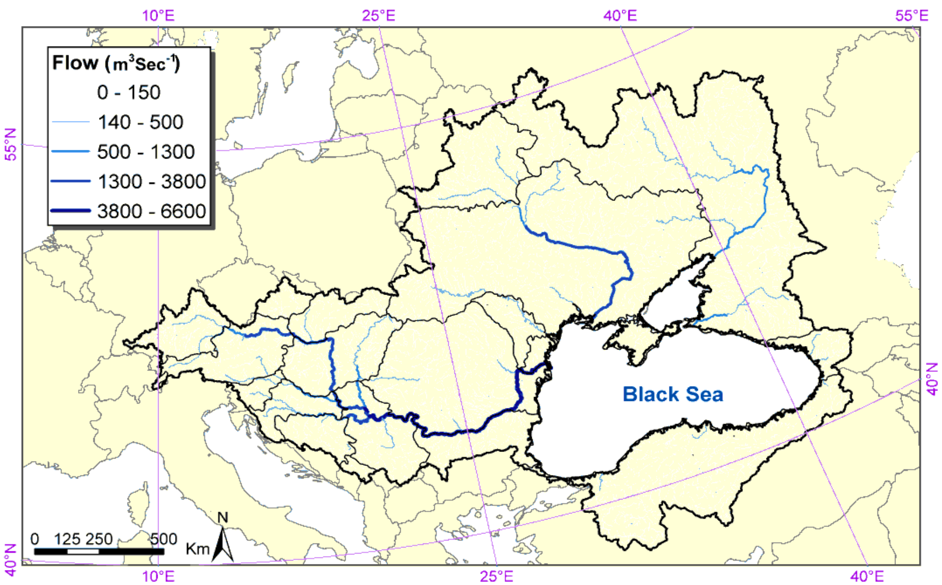
NO3 loads in Reaches

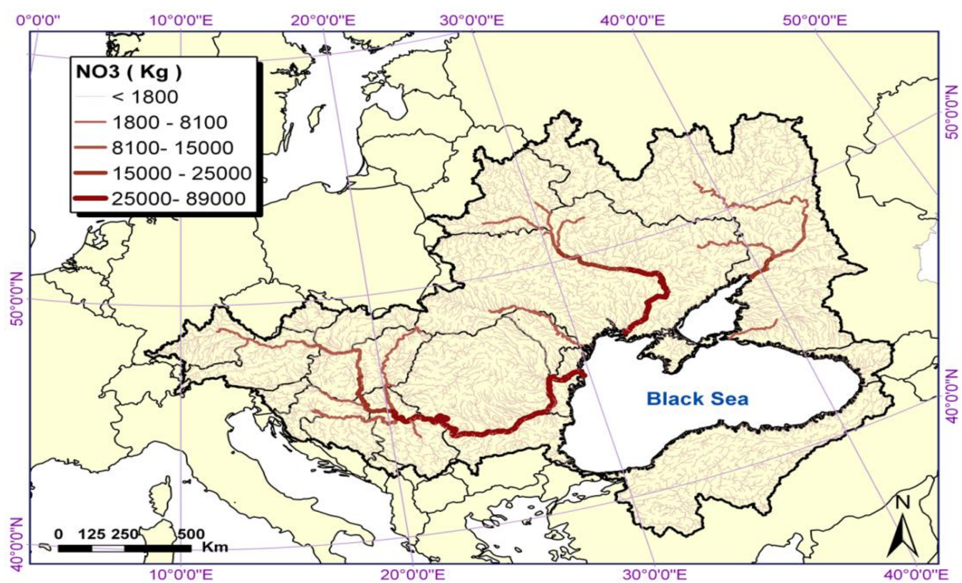




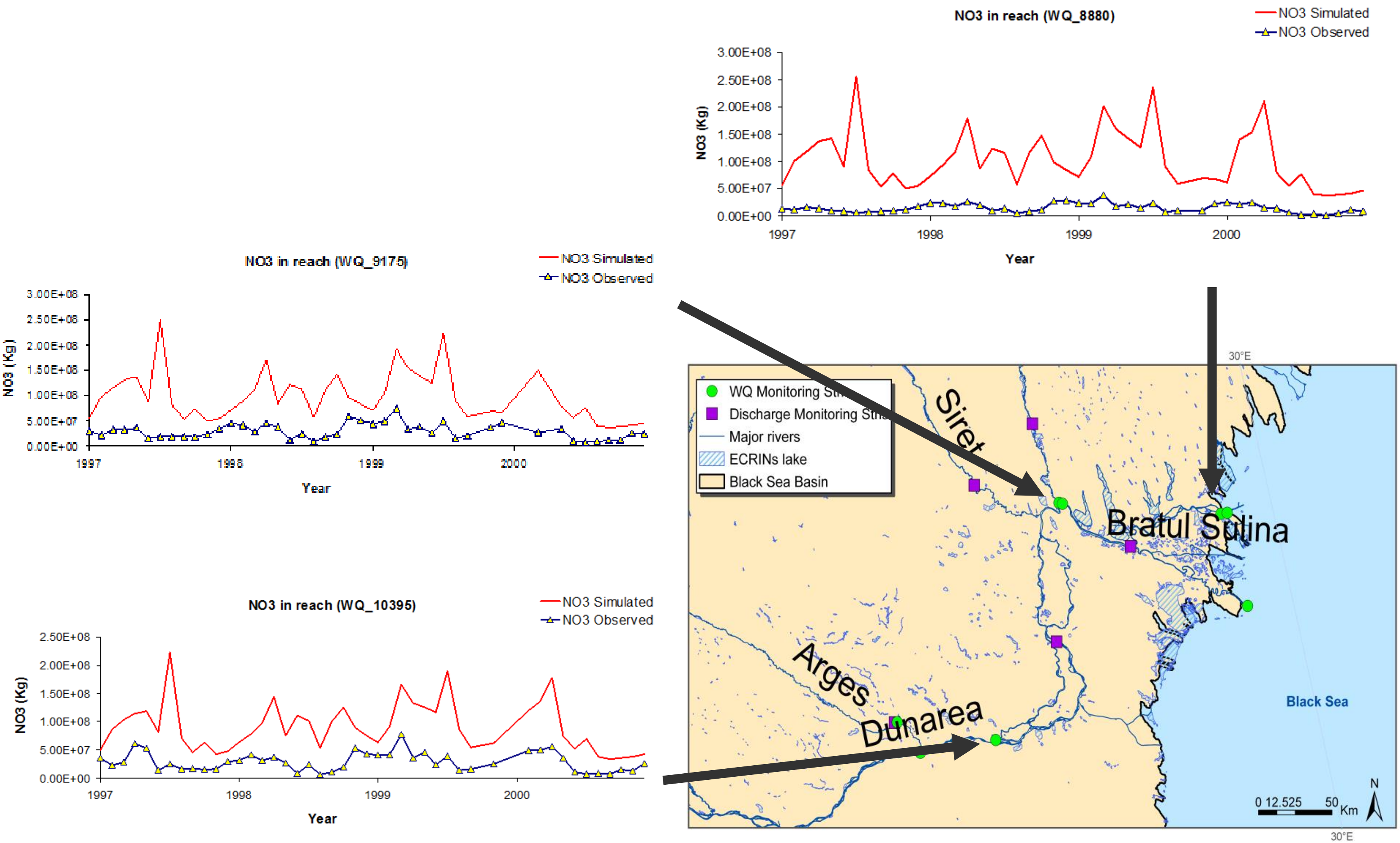
Calibration efficiency



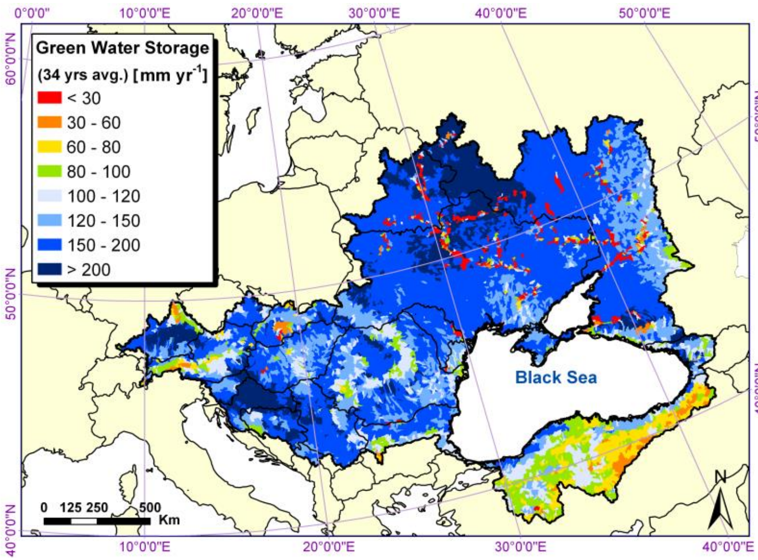


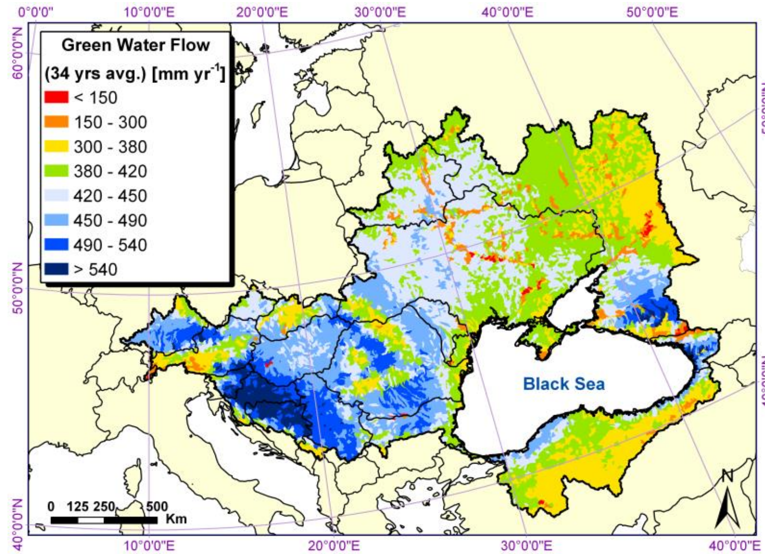


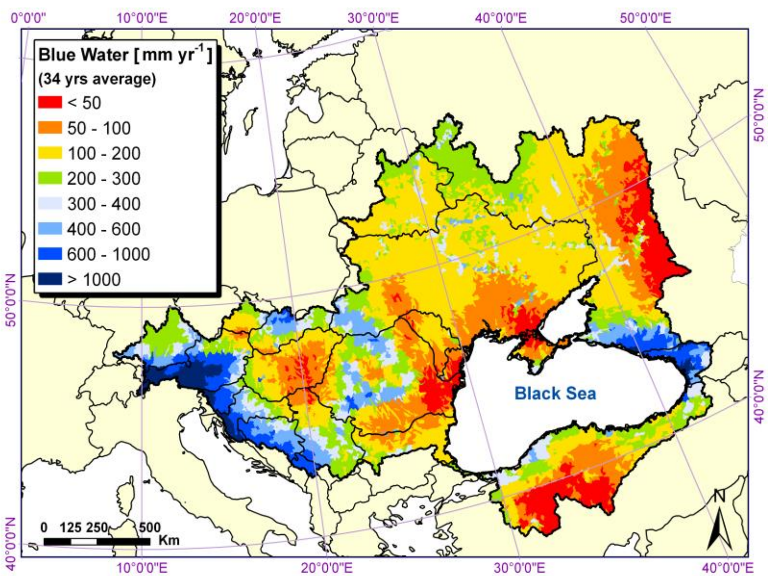
Danube Delta

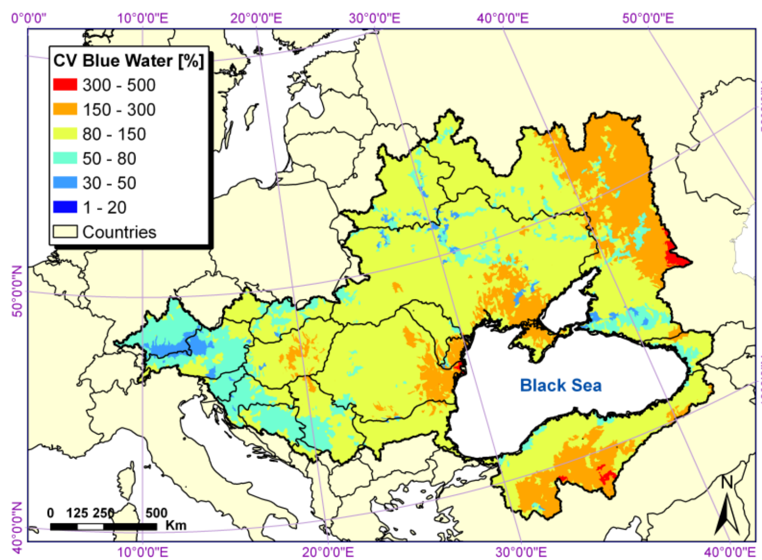


Blue Water, Green Water Flow and Green Water Storage

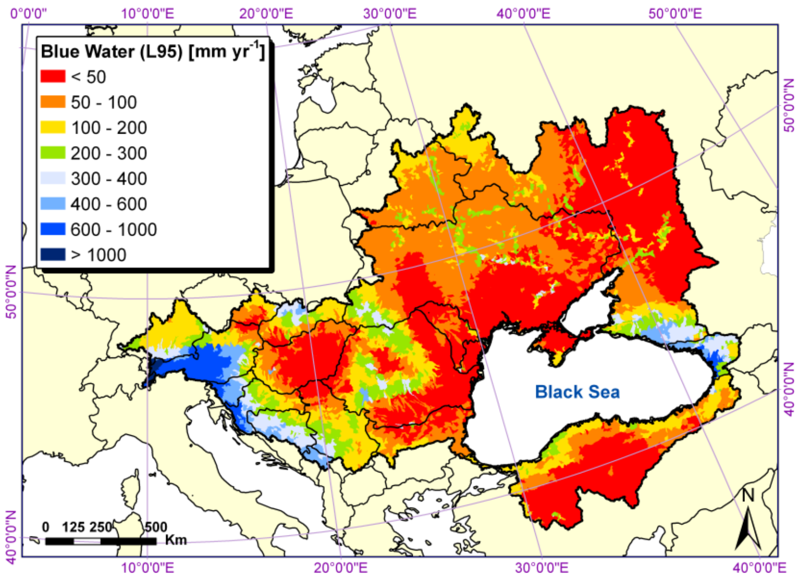


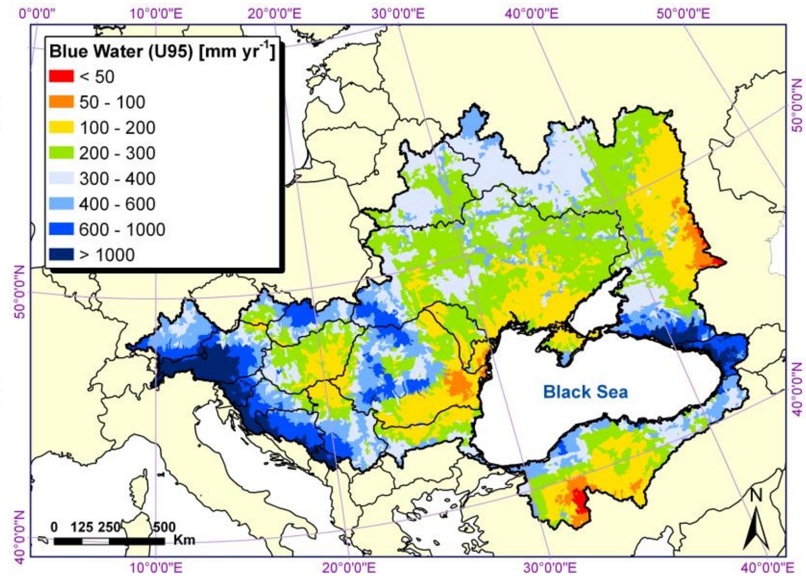


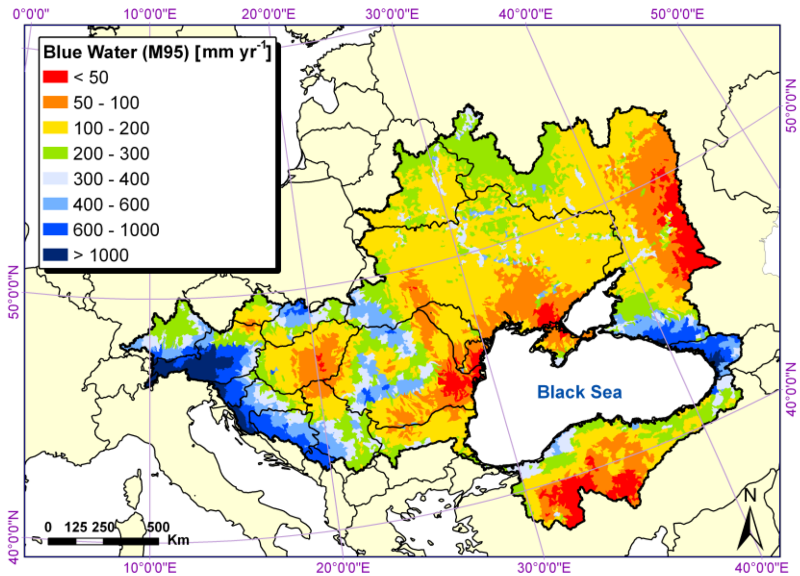




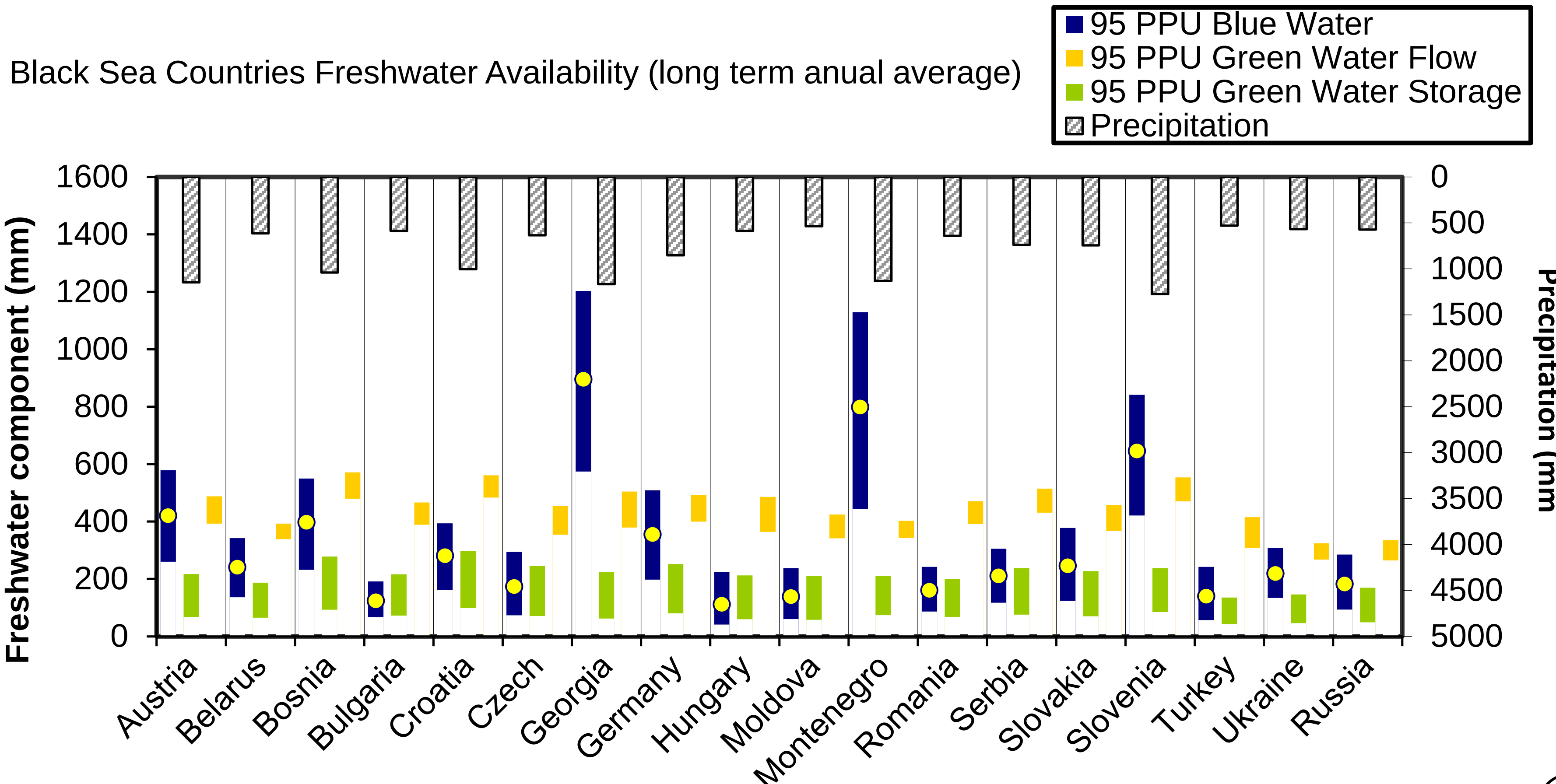
Uncertainties





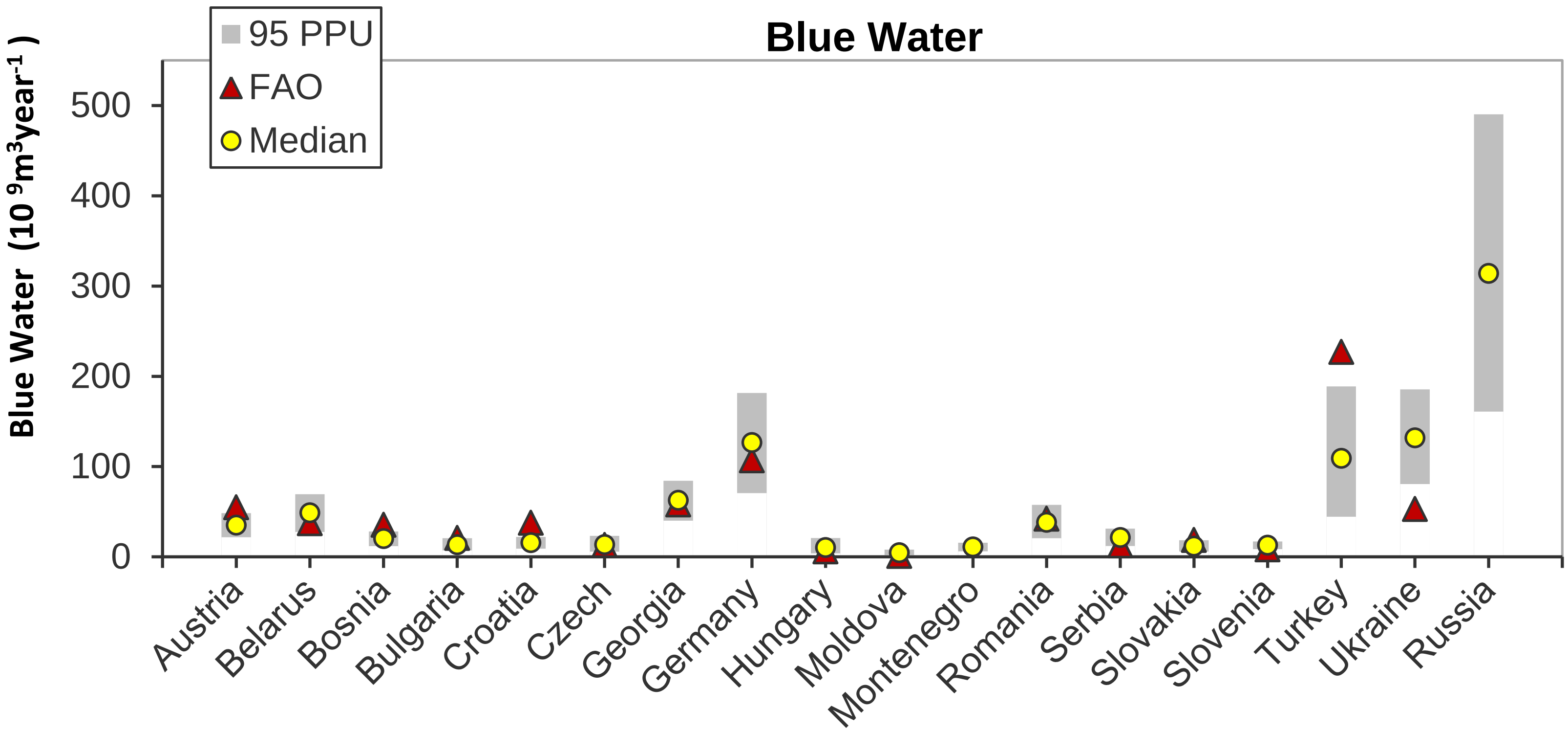


Internal renewable water resources, annual average (1970-2000)
Green Water Flow, Green Water Storage, Blue water (mm yr^{-1})

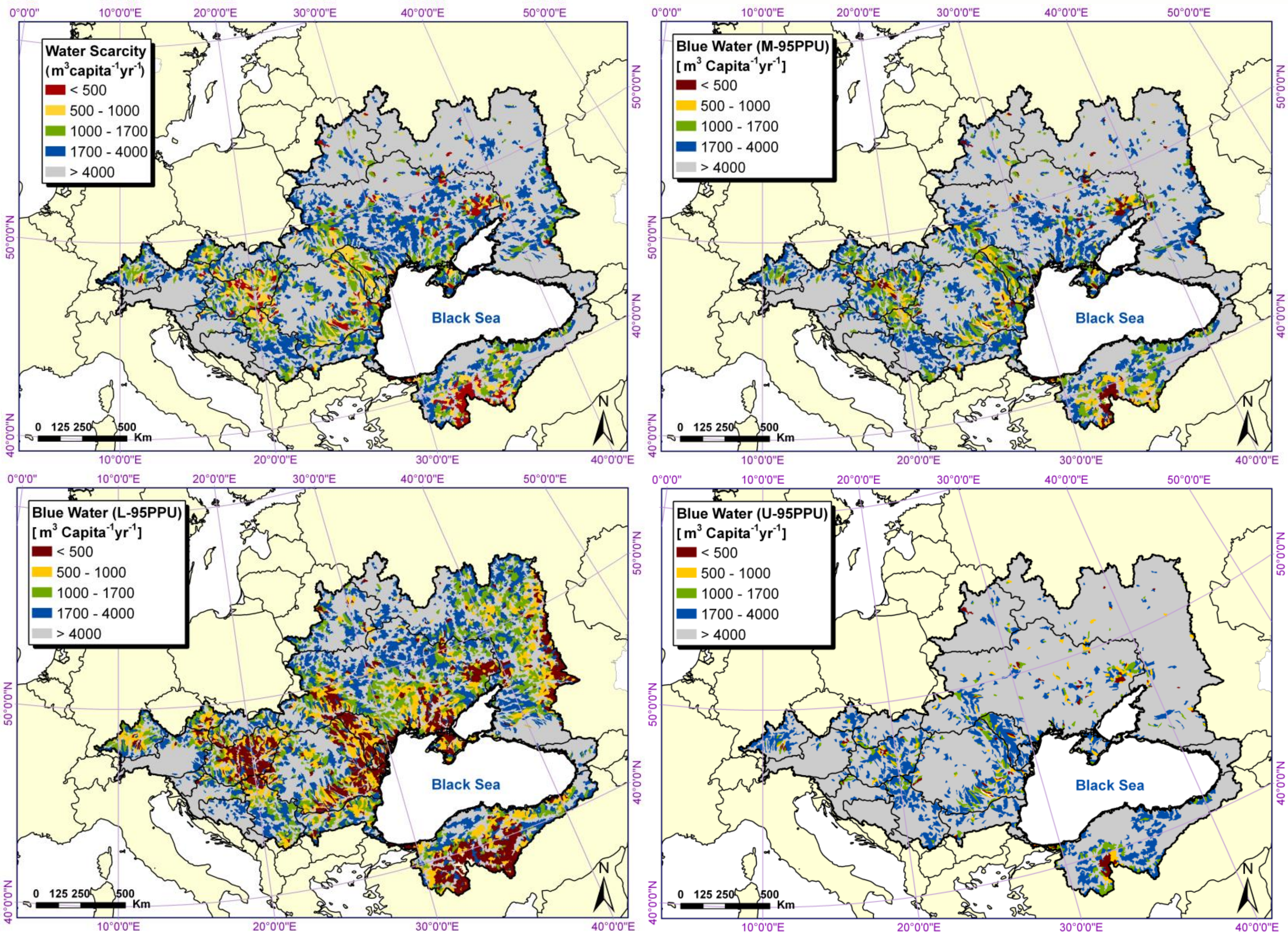


Internal renewable water resources (Blue water) (m^3 yr^{-1})

Comparison of the computed 95PPU intervals for the annual average (1970-2000) of the internal renewable water resources (IRWR) for BSC countries with the results from the FAO assessment **mm year^{-1}**



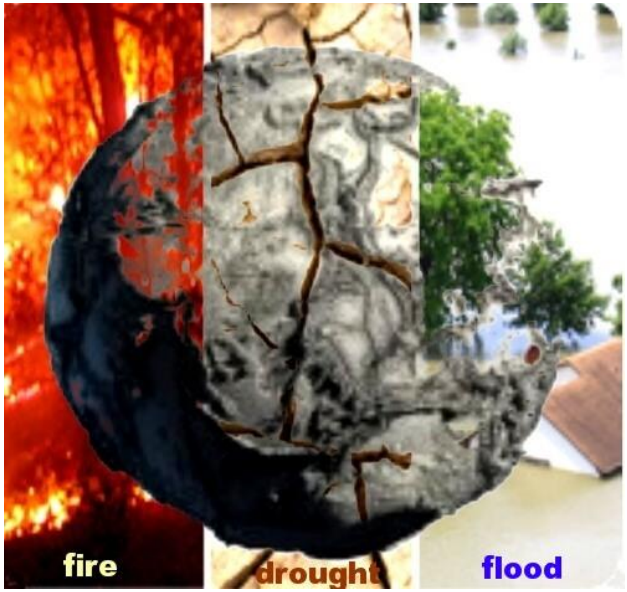
Blue Water Per capita, Water scarcity



Outlook

Research question3:

- Potential impacts of in climate change and land use change



Acknowledgements

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Dorian Gorgan

Victor Bacu

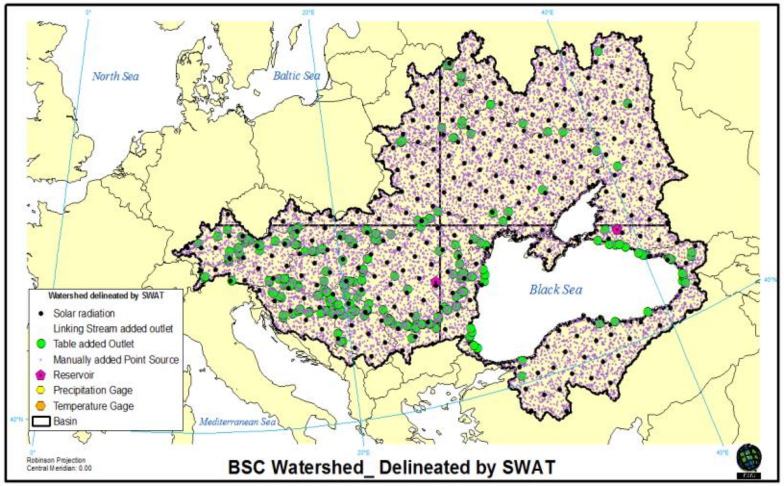
Rainer Sculin

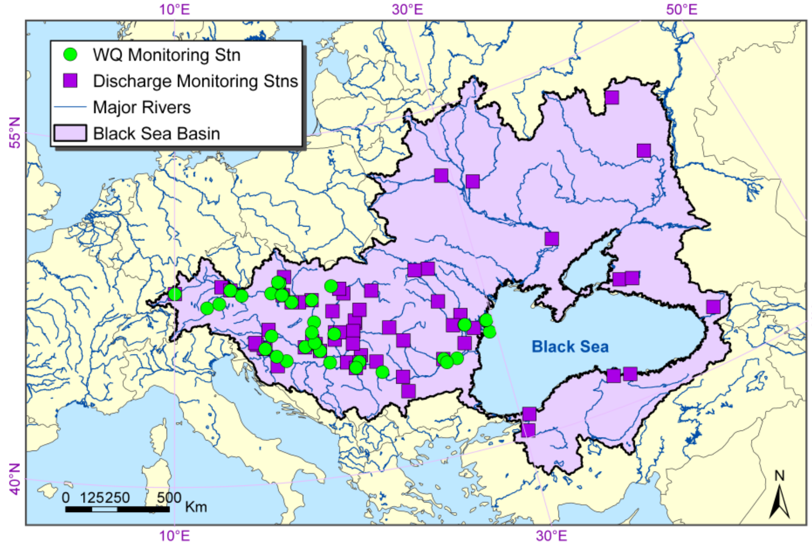
Key references

E. Rouholahnejad, K.C. Abbaspour, M. Vejdani, R. Srinivasan, R. Schulin, A. Lehmann: parallelization framework for calibration of hydrological models, *Environmental Modeling & sotware.*, **31** (2012) 28-36. http://dx.doi.org/10.1016/j.envsoft.2011.12.001

Elham. Rouholahnejad, Karim C. Abbaspour, R. Srinivasan , Victor Bacu , A. Lehmann: A high resolution calibrated water quantity and water quality model for Black Sea Basin, to be submitted in WRR, 2013

- Arc SWAT 2009
- 12982 subbasins
- 89202 Hrus
- CRU data sets as weather data
- Modis land cover
- Agricultural management for wheat, Maize and Barely
- Et Calculation based on Hargreaves Method
- Daily step SWAT run and monthly output printing was selected
- 37 yrs of simulation, 3 yrs warm up period(1970-2006)
- Each run 42 hours on a super power machin





Hydrology eq

SCS curve number equation (SCS, 1972)

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)}$$

I_a is initial abstraction which include surface storage, interception and infiltration prior to runoff, mm H_2O

S in retention parameter mm H_2O
The retention parameter varies spatially due to changes in soil, landuse and management and slope and temporally due to changes in soil water content.

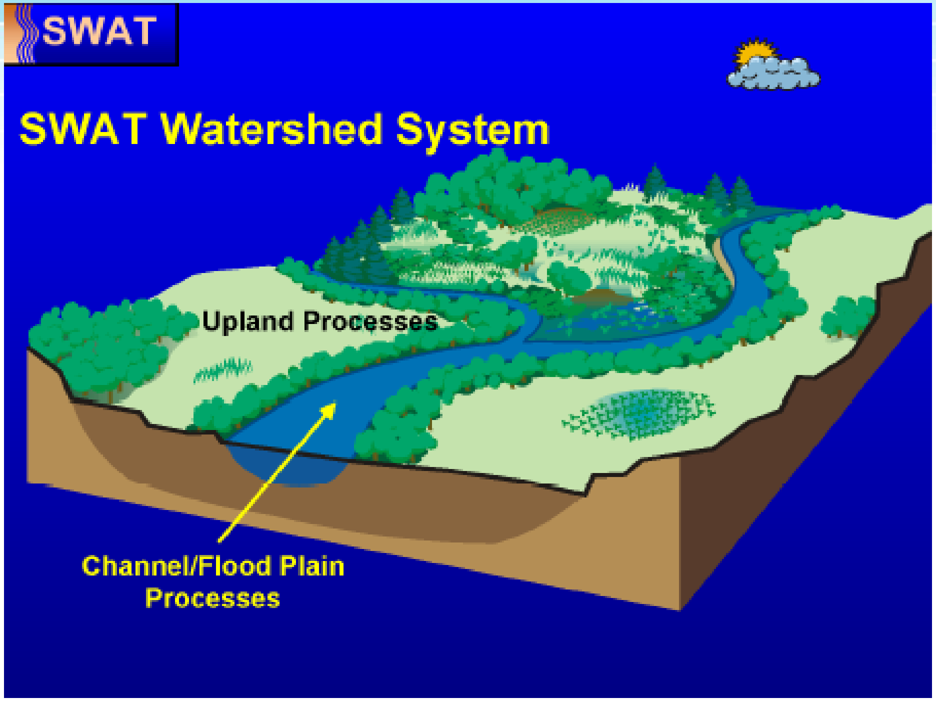
$$S = 25.4\left(\frac{1000}{CN} - 10\right)$$

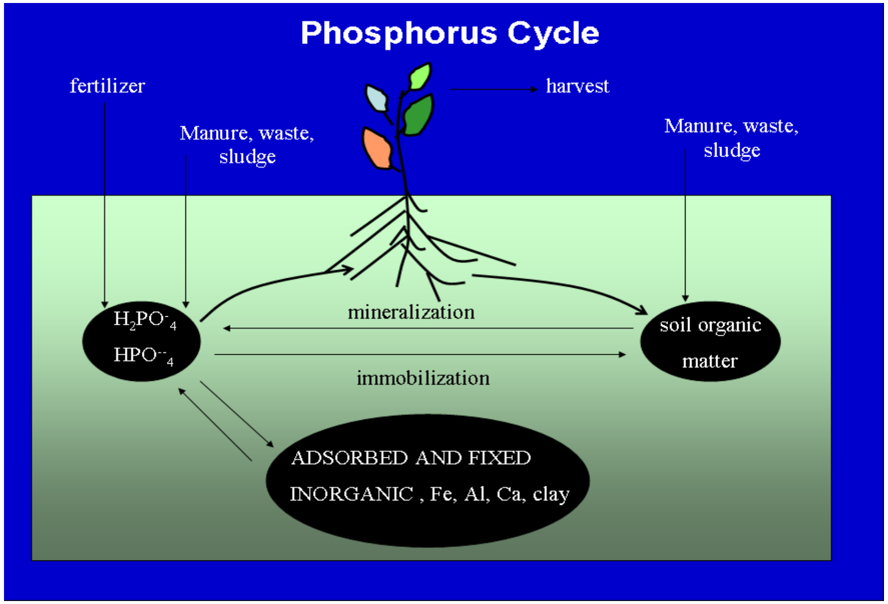
Where CN is the curve number of the day.
I_a = 0.2 S

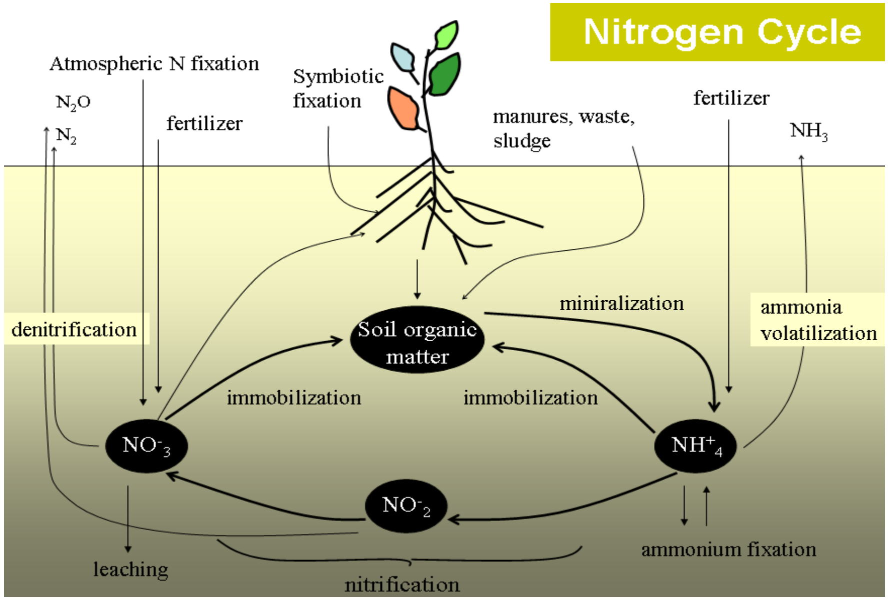
$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)}$$

The SCS Curve number is a fraction of the soil permeability, land use and antecedent soil water conditions.

Water quality eq


SWAT
SWAT Watershed System
Upland Processes
Channel/Flood Plain Processes


Phosphorus Cycle
fertilizer
Manure, waste, sludge
harvest
Manure, waste, sludge
$H_2PO^-_4$
HPO^{--}_4
mineralization
immobilization
soil organic matter
ADSORBED AND FIXED INORGANIC , Fe, Al, Ca, clay


Nitrogen Cycle
Atmospheric N fixation
N_2O
N_2
fertilizer
Symbiotic fixation
manures, waste, sludge
fertilizer
NH_3
denitrification
Soil organic matter
miniralization
ammonia volatilization
immobilization
immobilization
NO^-_3
NH^+_4
NO^-_2
leaching
nitrification
ammonium fixation

Crop growth eq