Hydrological models of Black Sea and Europe

Sardinia, 2015

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Eawag: Swiss Federal Institute of Aquatic Science and Technology

European Projects

EnviroGrids, EU FP7

Building Capacity for Black Sea Basin Observation and Assessment System Supporting Sustainable Development

GENESIS, EU FP7

Groundwater and Dependent Ecosystems: NEw Scientific and Technical BasIS for Assessing Climate Change and Land-use Impacts on Groundwater Systems

Background and Challenges

- Inadequate resource management
- Environmental degradation, sea pollution
- Transboundary effects
- Agricultural water demands and fertilizer use
- Water stresses
- High vulnerability towards climate change
- Flood/droughts risks

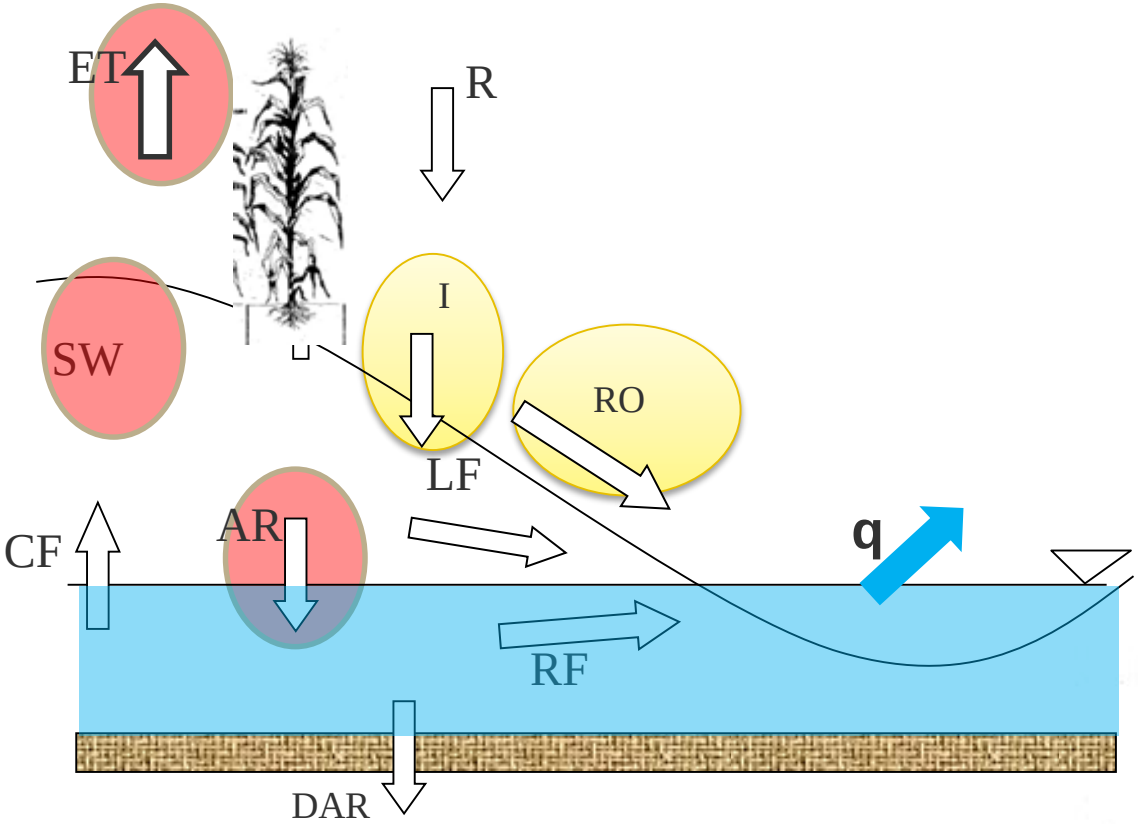
Objectives

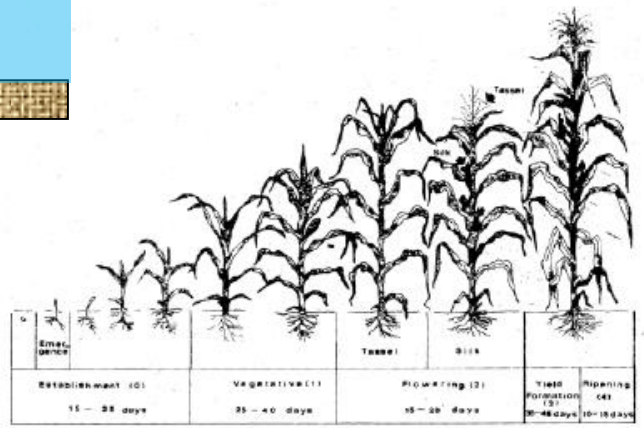
- Build an Agro-hydrologic model of the Black Sea Basin and Europe at high resolution simulating nitrate pollution

- Calibrate/validate with uncertainty analysis the Agro-hydrologic model

- Assess the impacts of climate change and landuse change on water resources

Why agro-hydrologic model?





Steps in building a SWAT Project

1- Build databases

2- Build the project in ArcSWAT, QSWAT

3- Calibrate, validate, with sensitivity and uncertainty analyses

4- Analyze outputs

Build databases

On the one hand, there is never enought data to build and calibrate a model,

On the other hand, there are more and more new databases becoming available from different sources

Build Databases

DEM: Source, Resolution

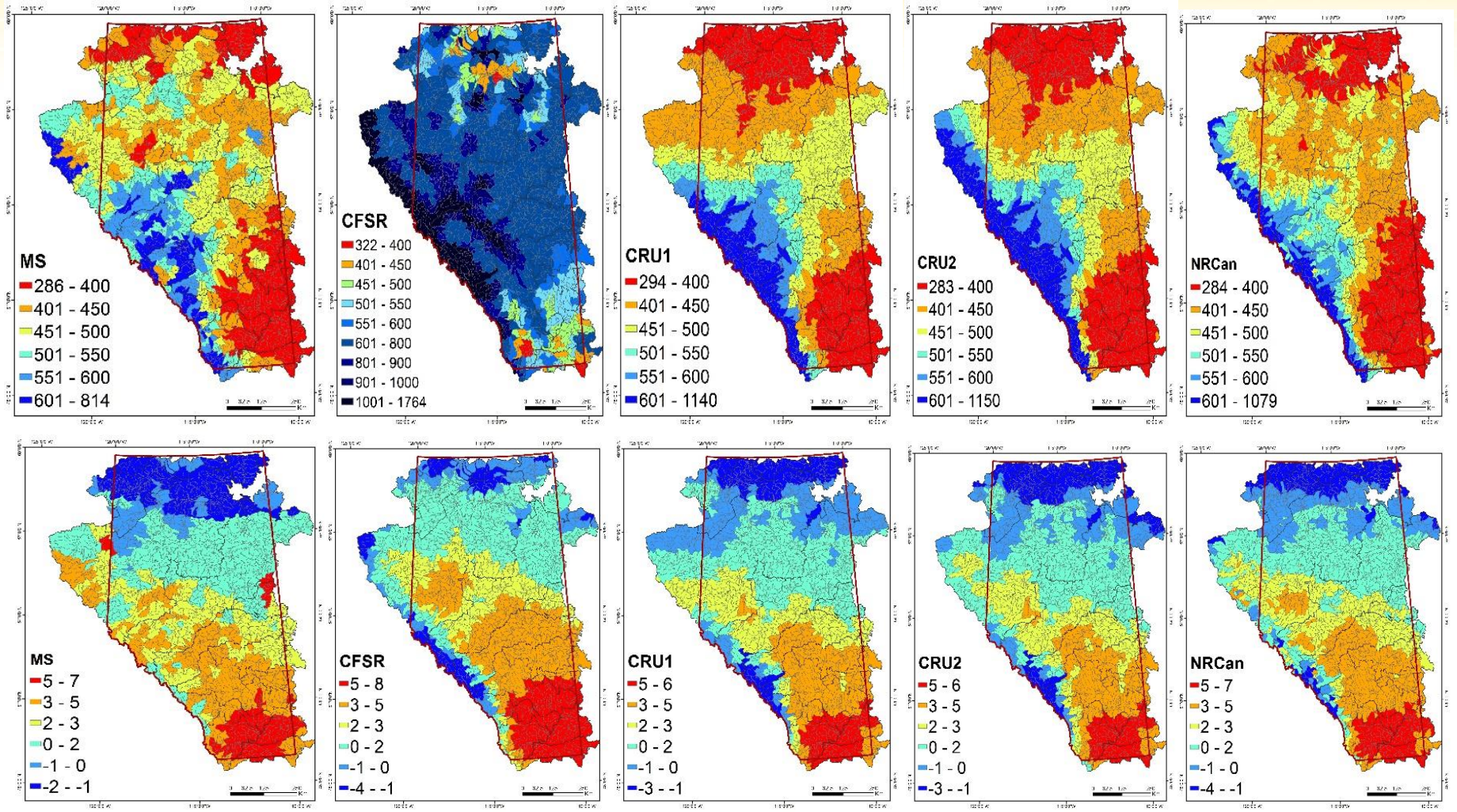
Soil: European, FAO, Local, etc.

Landuse: GlobCover ESA, Global Landuse USGS, MODIS land cover, GlobCorine ESA, Local, etc.

Climate: European Climate Assessment Dataset (ECAD), Climate Research Unit (CRU), Climate Data Guide (NCAR), Measured data, etc.

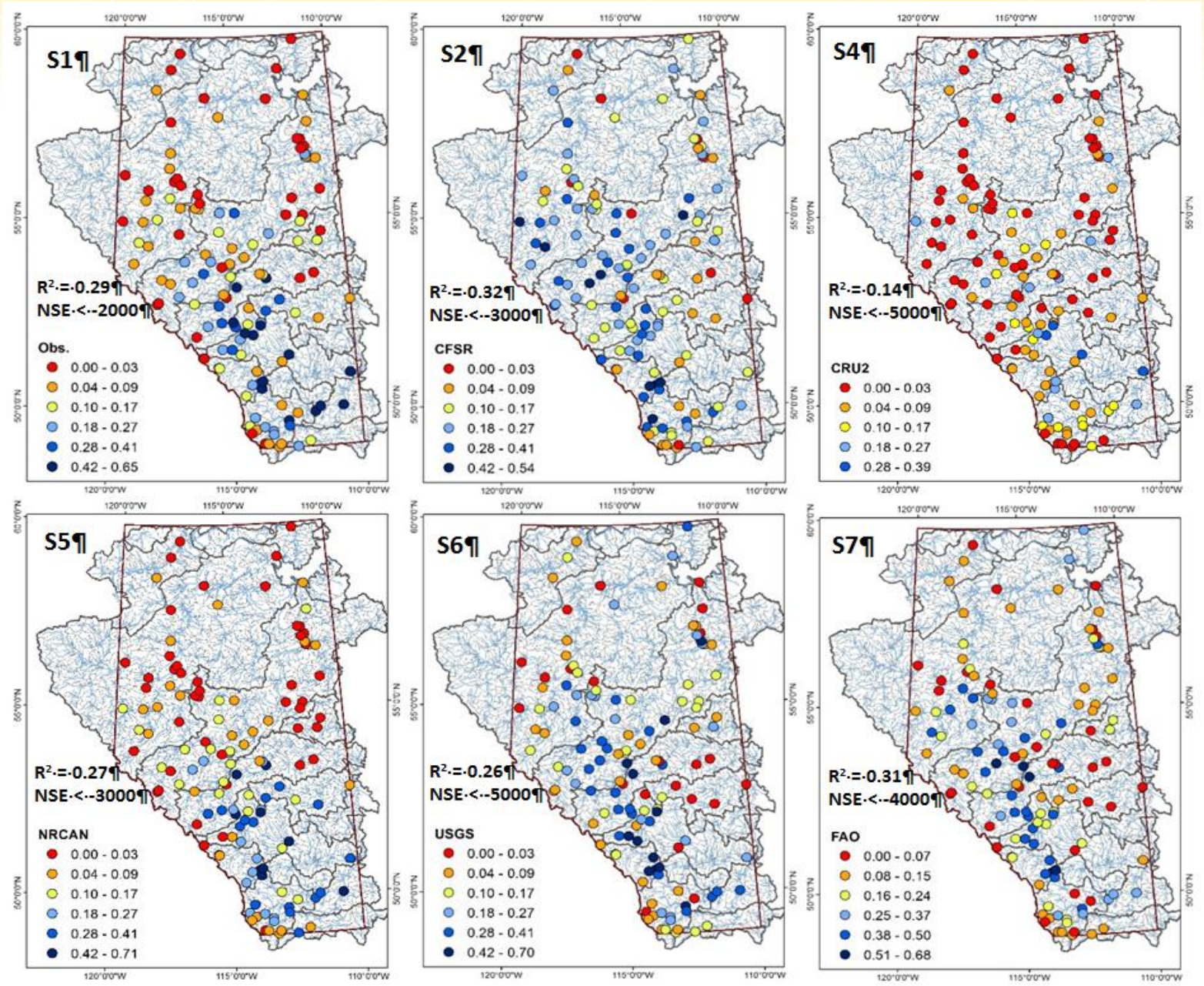
River: Ecrin, others

Climate data



Spatial distribution of the 25year (1983–2007) average precipitation (mm; above) and temperature (°C; below) across study area from the observed MS data and the four gridded climate datasets.

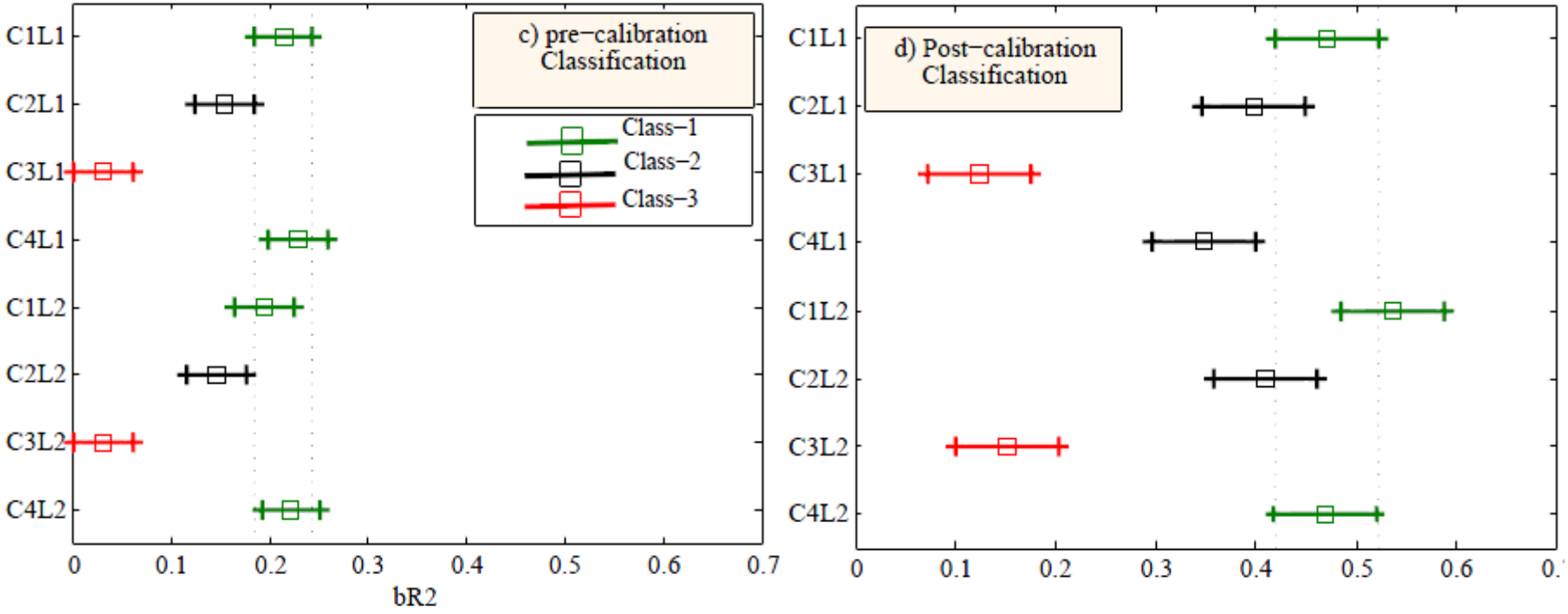
Example Alberta

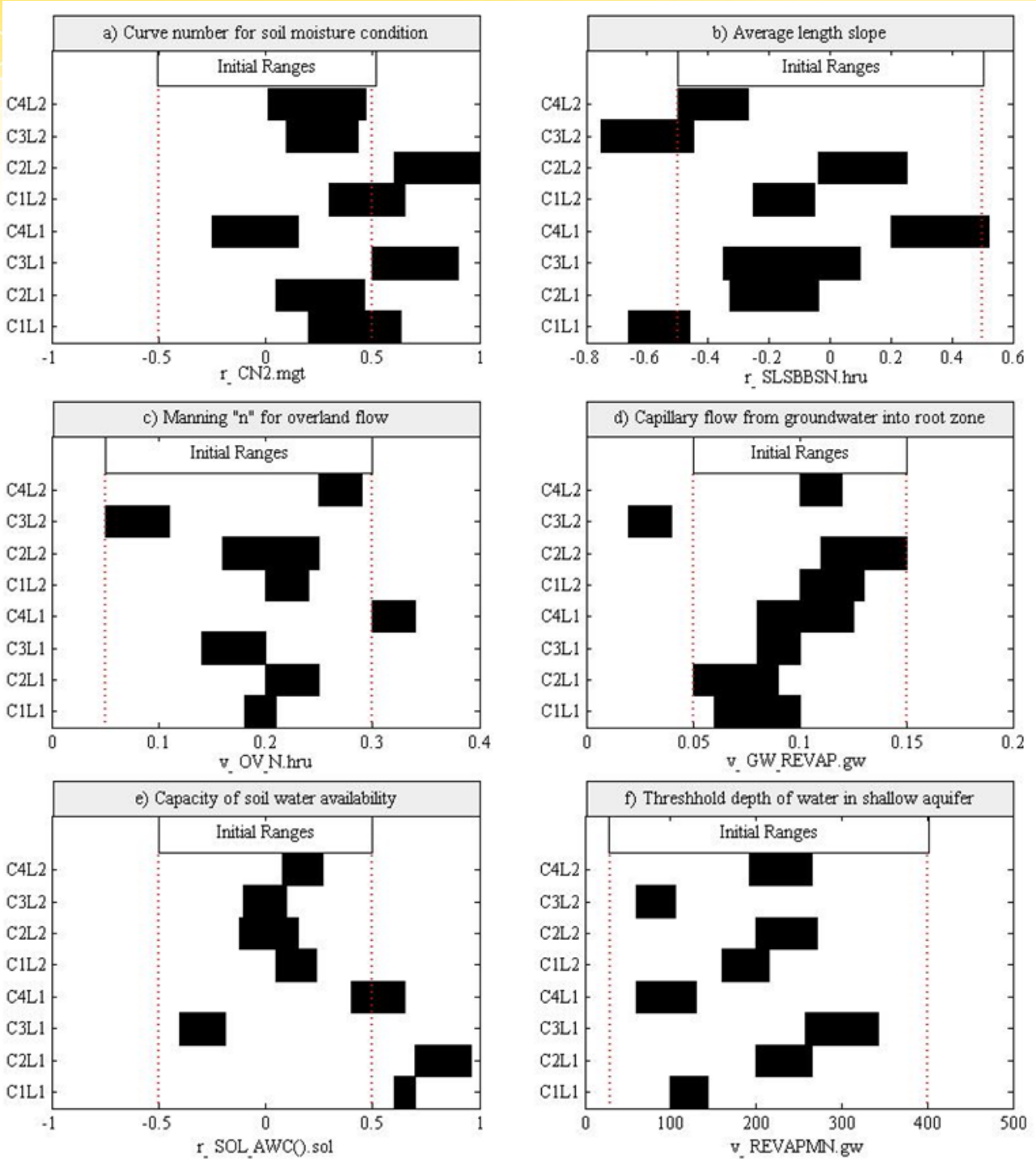


Climate data comparison

			Climate database			
River	Station Name	GRDC	ECAD	CRU	NCAR	Observed
Volga	Volgograd	8141	5570	6924	5951	7465
Danube	Ceatal Izmail	6415	3243	5244	4724	4204
Pechora	Oksino	4444	1849	2396	2330	2277
North. Dvina	Ust-Pinega	3331	1419	1597	1470	1705
Rhine	Lobith	2229	1725	2065	2110	1589
Rhone	Beaucairw	1709	1735	1808	1707	1364
Sava	Sremska M.	1563	411	1078	881	973
Po	Pontelagoscuro	1514	1108	1589	1424	1210
Maros	Mako	173	9	95	86	85
Olt	Stoenesti	161	21	62	67	47
Szamos	Satu Mare	126	41	63	81	54
Trent	Colwick	85	67	65	59	61
Thames	Teddington	82	37	47	72	36
Root Mean Square Error			**5500**	3360	**4100**	**3900**

Example Karkheh, Iran




a) Curve number for soil moisture condition
Initial Ranges
C4L2
C3L2
C2L2
C1L2
C4L1
C3L1
C2L1
C1L1
-1
-0.5
0
0.5
1
r_ CN2.mgt
b) Average length slope
Initial Ranges
C4L2
C3L2
C2L2
C1L2
C4L1
C3L1
C2L1
C1L1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
r_ SLSBBSN.hru
c) Manning "n" for overland flow
Initial Ranges
C4L2
C3L2
C2L2
C1L2
C4L1
C3L1
C2L1
C1L1
0
0.1
0.2
0.3
0.4
v_ OV_N.hru
d) Capillary flow from groundwater into root zone
Initial Ranges
C4L2
C3L2
C2L2
C1L2
C4L1
C3L1
C2L1
C1L1
0
0.05
0.1
0.15
0.2
v_ GW_REVAP.gw
e) Capacity of soil water availability
Initial Ranges
C4L2
C3L2
C2L2
C1L2
C4L1
C3L1
C2L1
C1L1
-1
-0.5
0
0.5
1
r_ SOL_AWC().sol
f) Threshhold depth of water in shallow aquifer
Initial Ranges
C4L2
C3L2
C2L2
C1L2
C4L1
C3L1
C2L1
C1L1
0
100
200
300
400
500
v_ REVAPMN.gw

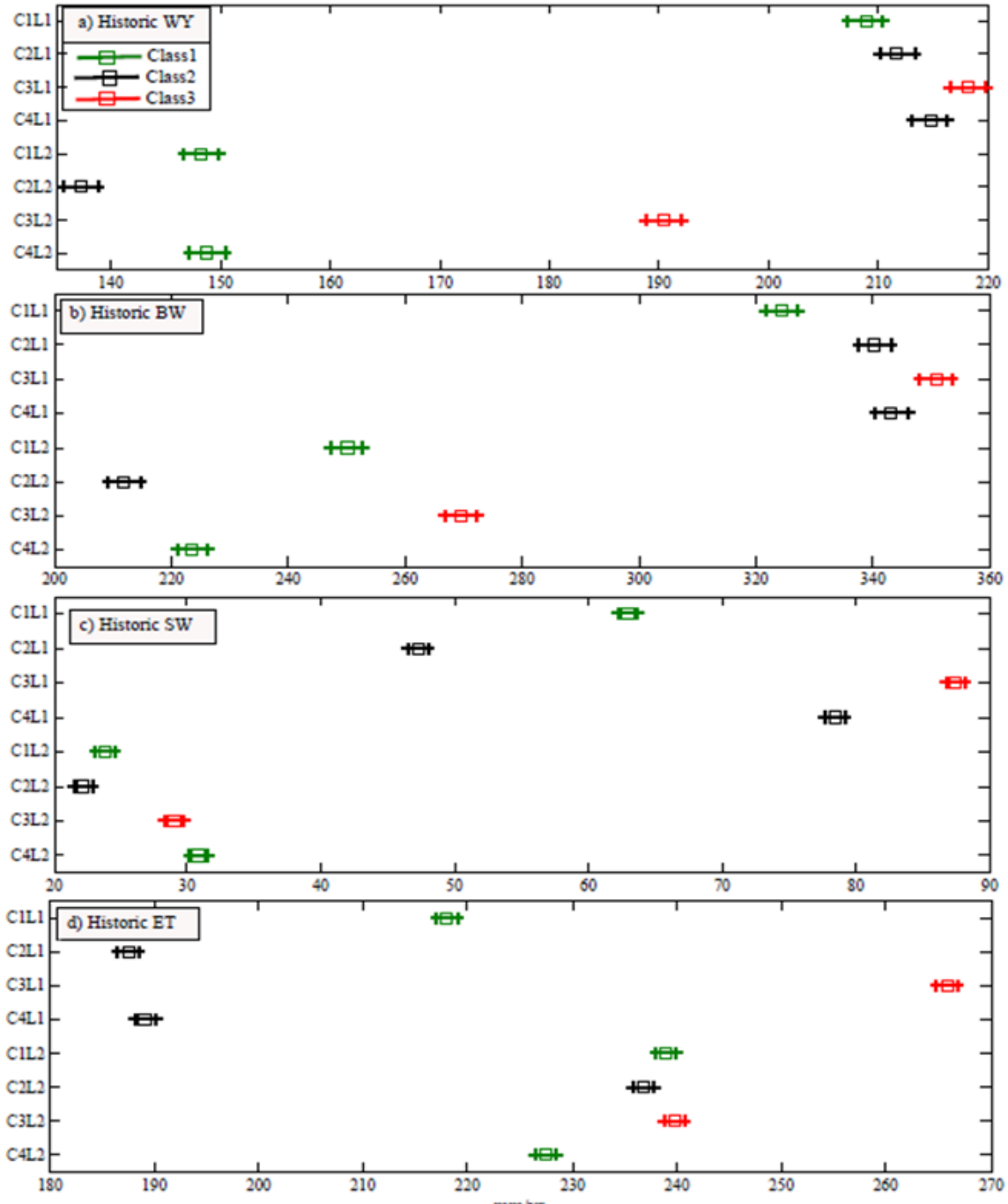
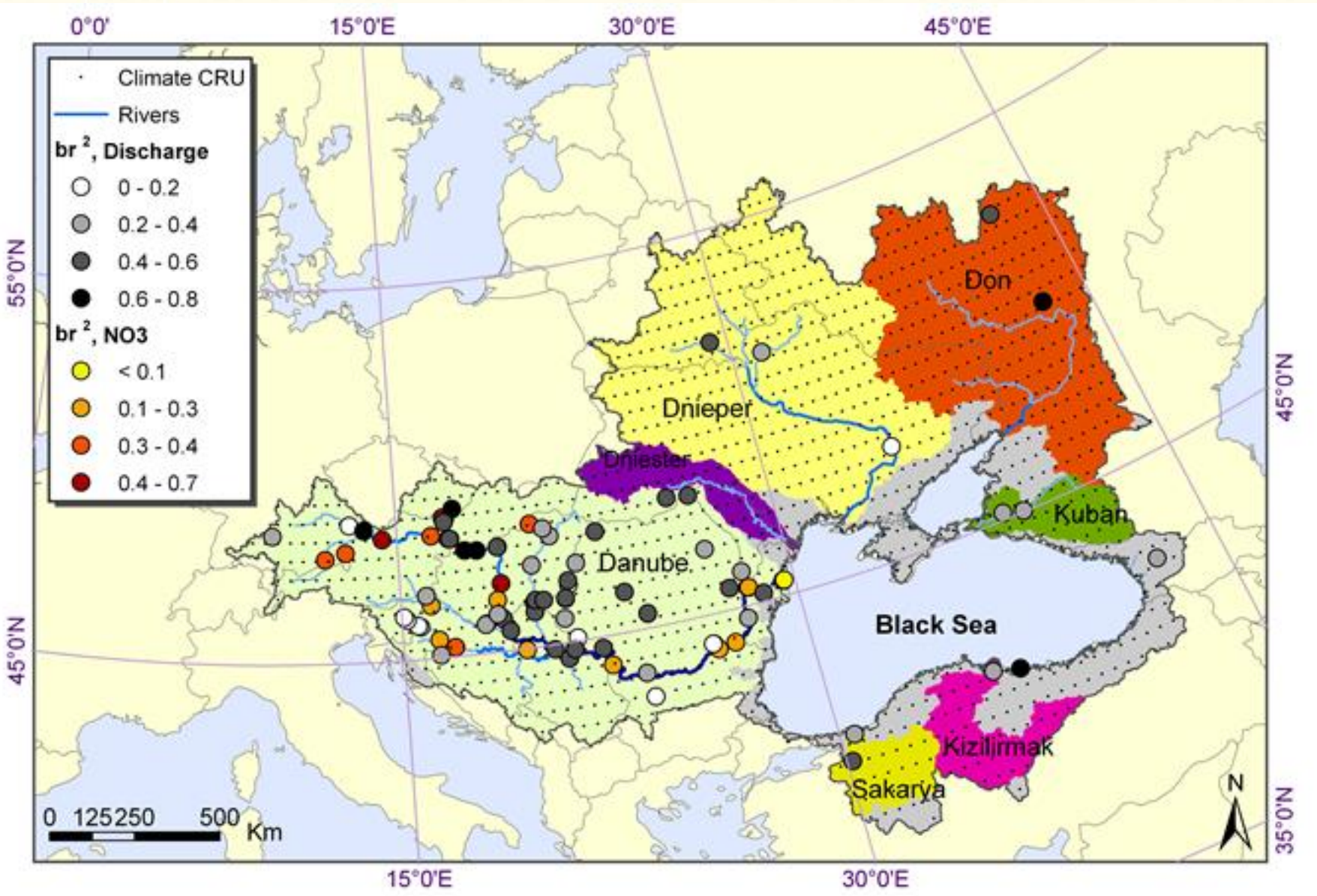

a) Historic WY
Class1
Class2
Class3
C1L1
C2L1
C3L1
C4L1
C1L2
C2L2
C3L2
C4L2
140 150 160 170 180 190 200 210 220
b) Historic BW
200 220 240 260 280 300 320 340 360
c) Historic SW
20 30 40 50 60 70 80 90
d) Historic ET
180 190 200 210 220 230 240 250 260 270
mm/yr

Figure 3

Conclusion:

This is not a good news!

Water Quality



Point Source

$$NO_3 = \alpha_i * POP_i * \left[\left(1 - \frac{S * N}{PE}\right) + \left(\frac{(1 - T_{eff}) * S * N}{PE}\right)\right]$$

Zessner et al, (2005)

- NO_3 is the nitrate loading to river (g day^{-1})

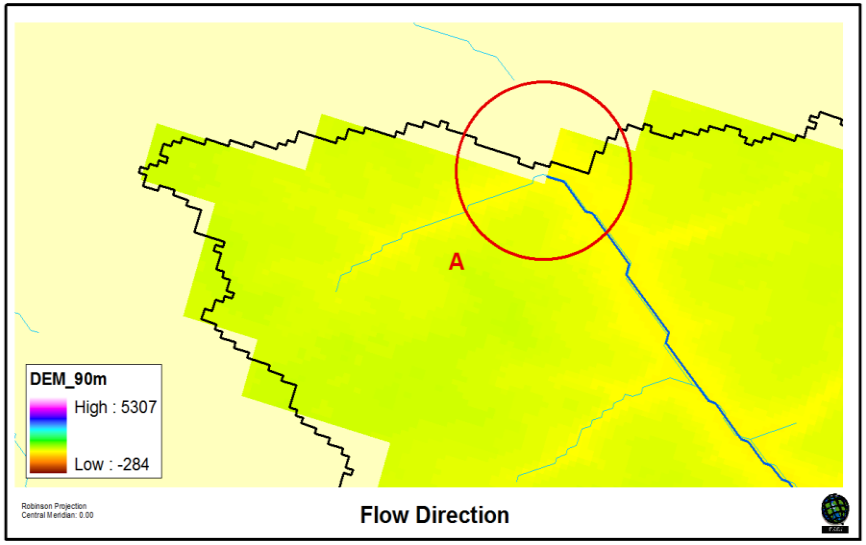
-α, is a correction factor

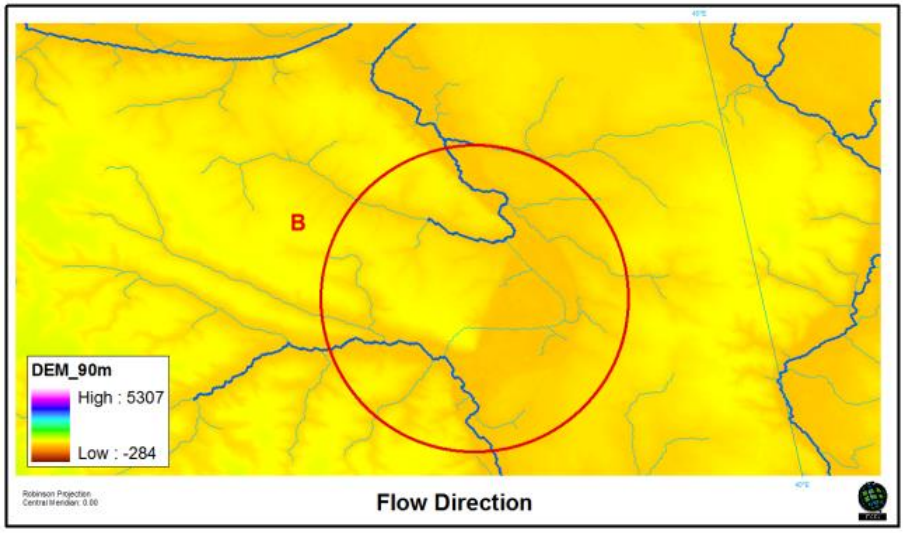
- POP_i is the population of subbasin *i*,

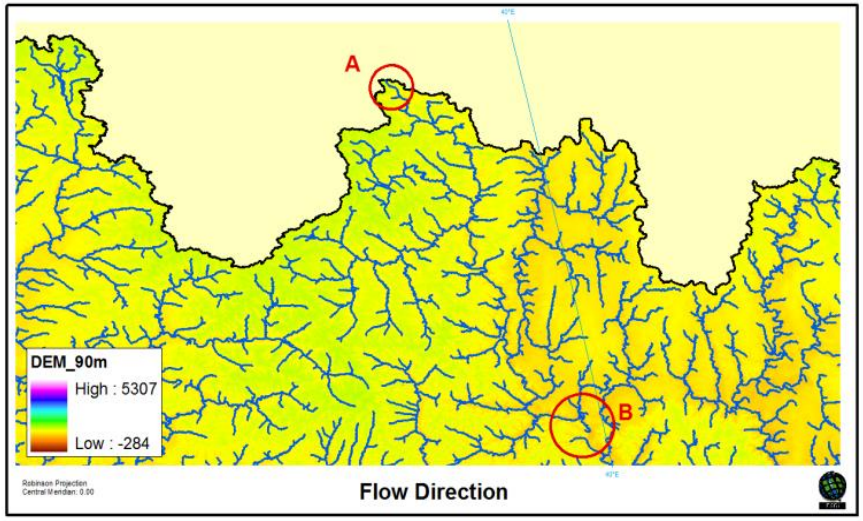
-T_{eff} is the wastewater treatment efficiency

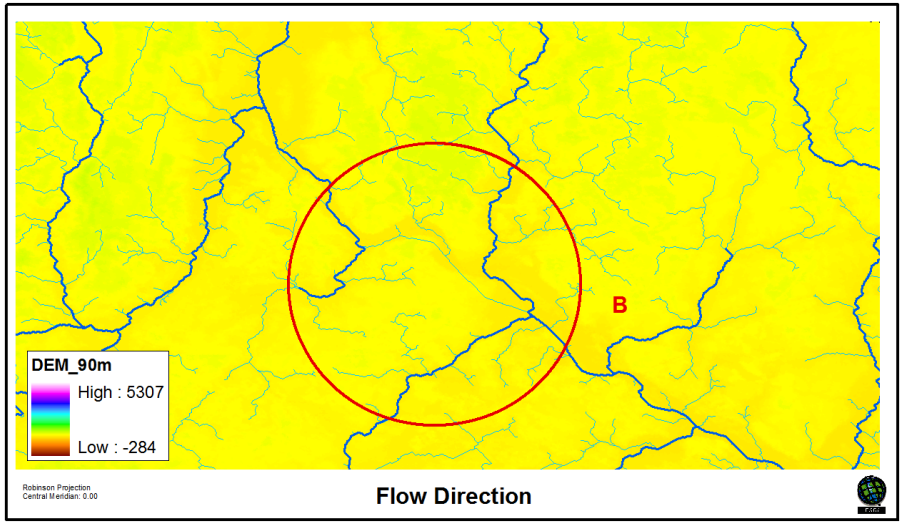
-*S* is percentage of the population connected to any kind of sewage treatment.

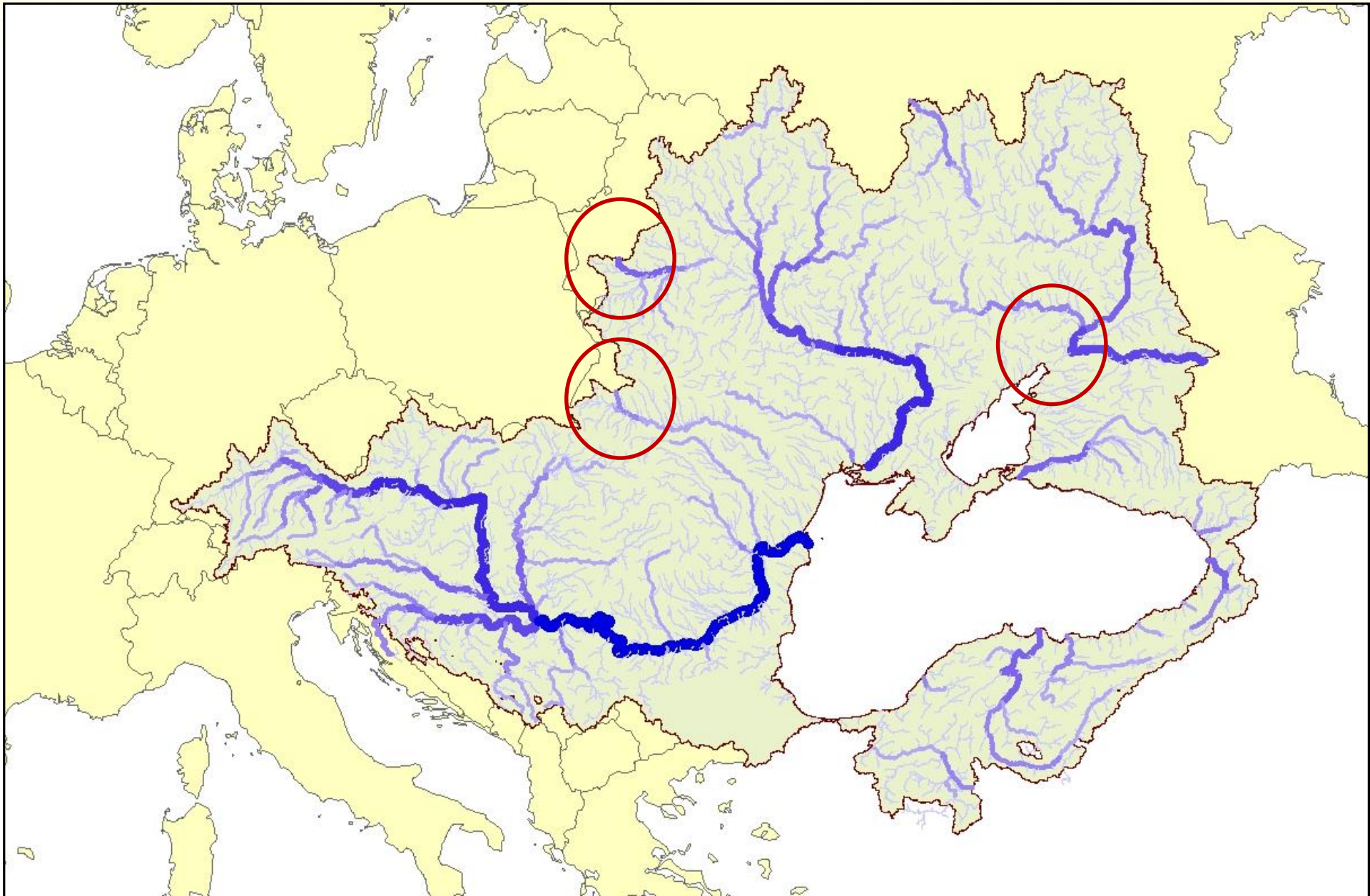
Structural problems

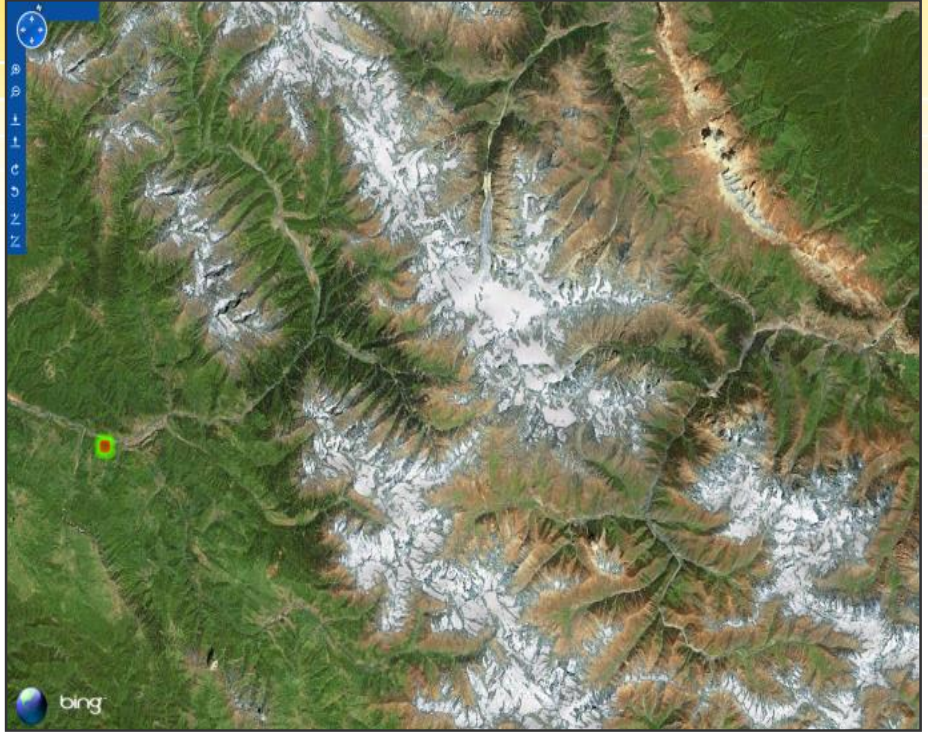


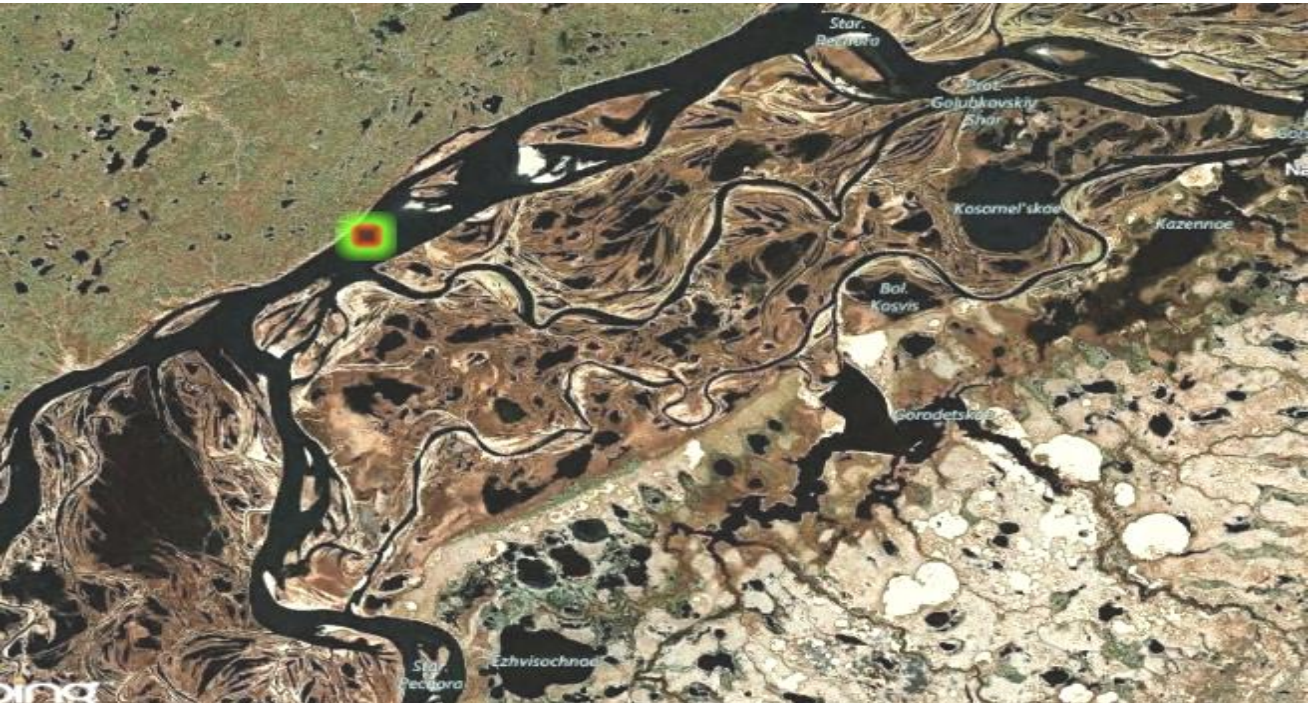




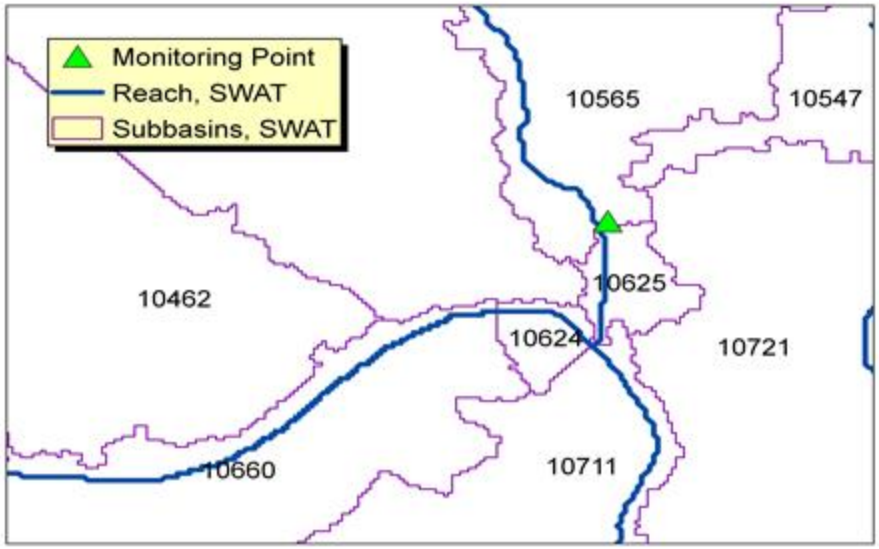





bing

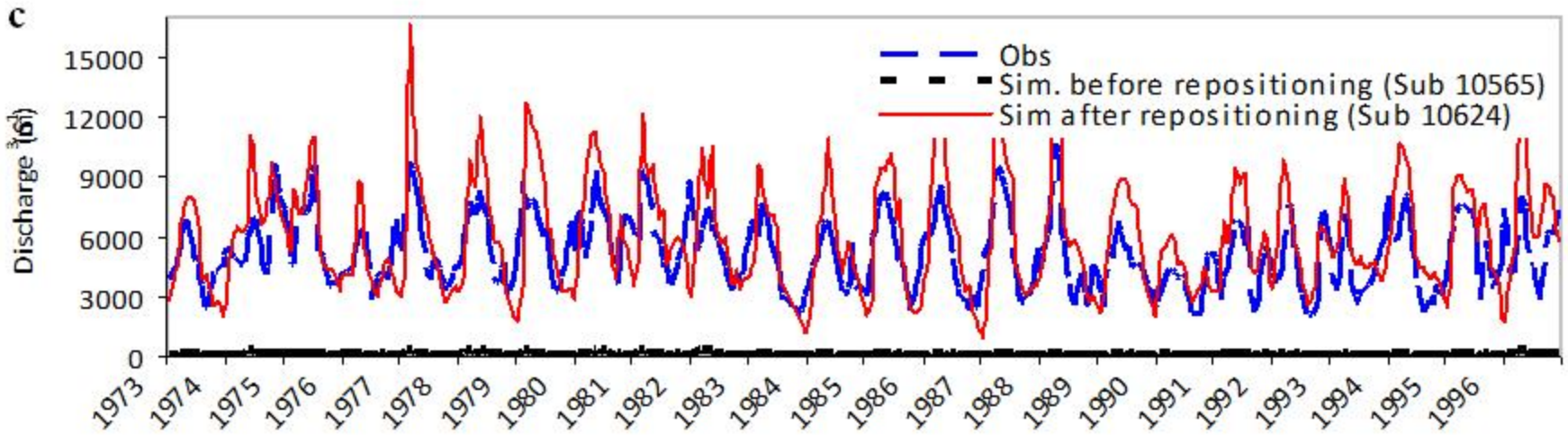

Bol. Golubkovskiy Shar
Kosomel'skoe
Kazennoe
Bol. Kosvis
Ezhvisochnoe

a

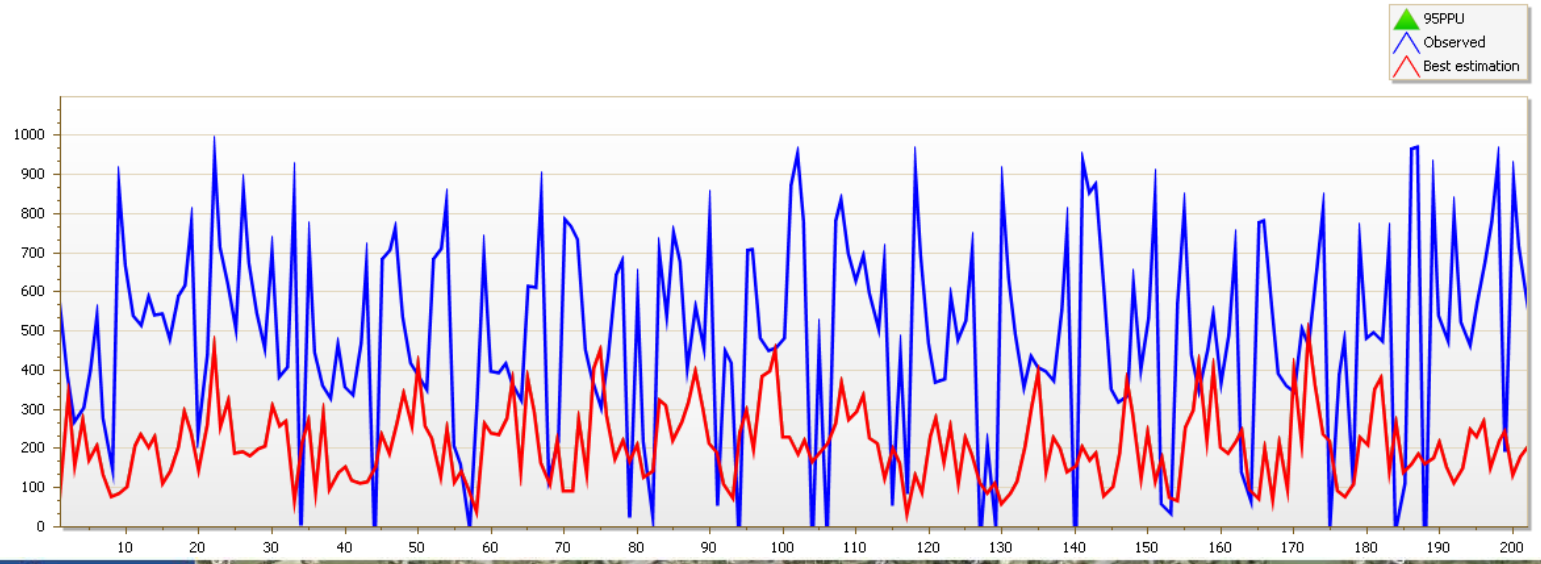

Monitoring Point
Reach, SWAT
Subbasins, SWAT
10565
10547
10625
10462
10624
10721
10660
10711

b

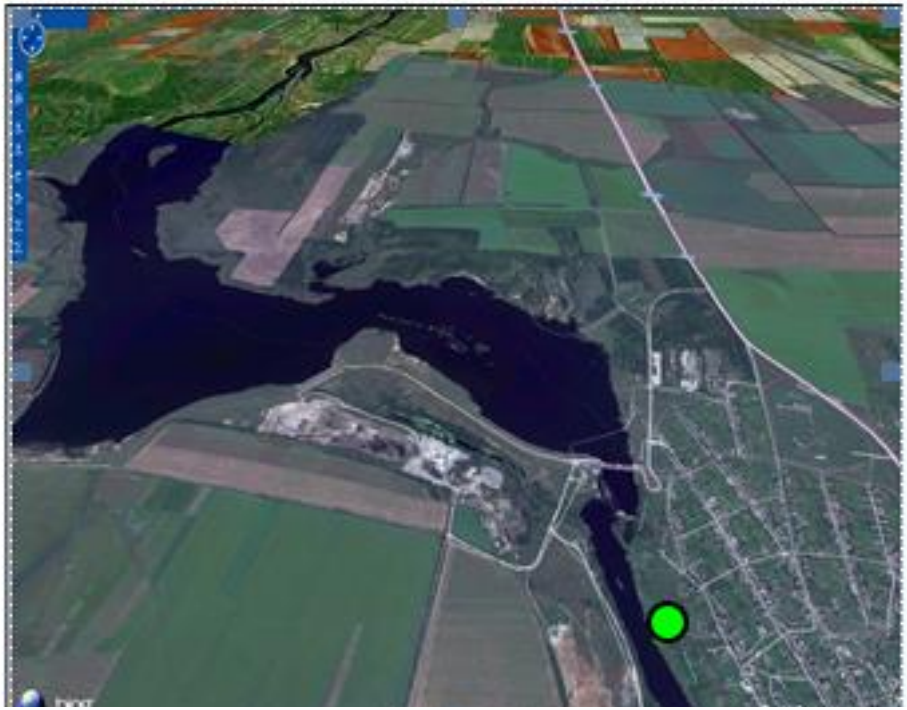
c

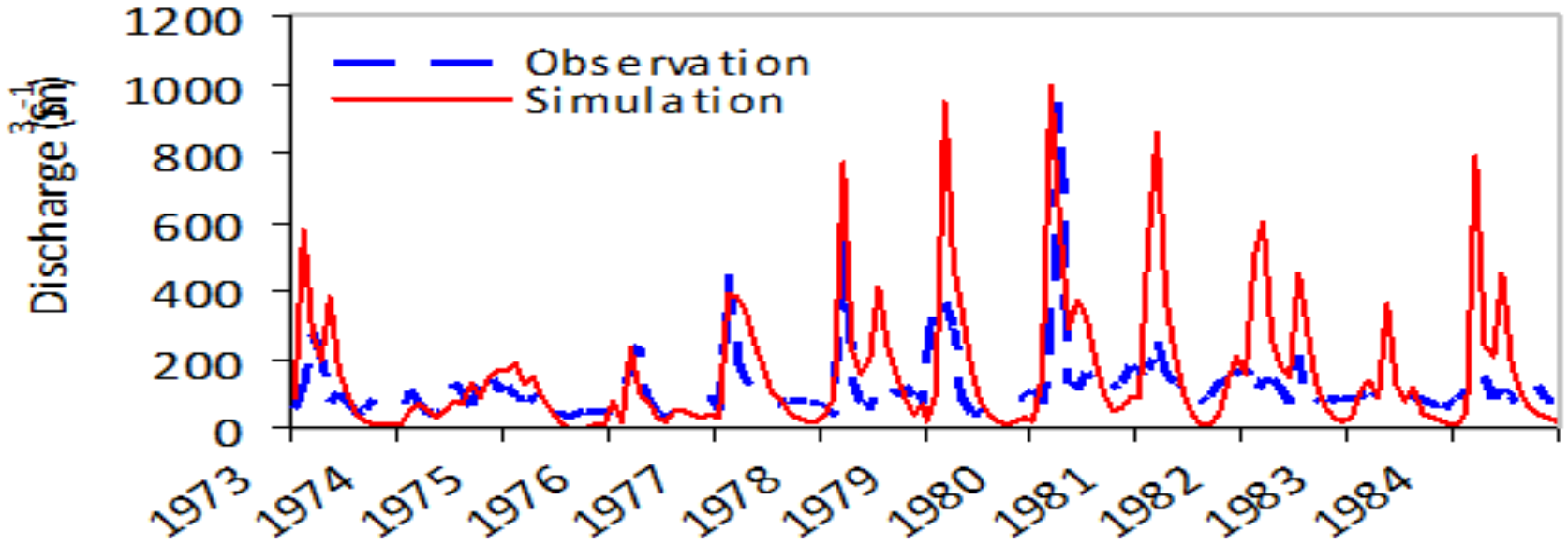

Obs
Sim. before repositioning (Sub 10565)
Sim after repositioning (Sub 10624)
Discharge (m3/s)
15000
12000
9000
6000
3000
0
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996

q_7460


95PPU
Observed
Best estimation
1000
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200


Leonhard-Paminger-Straße
Neuer Stadtpark
Klinikum Passau
Neuburger Straße
Graf-Salm-Straße
Fuchsbauerweg
Ingling
1151
Schwendt
Hamberg Bezirksstraße
Güterweg Raden
Güterweg Hof
Eduard-Hamm-Straße
Poitlbauerweg
Latitude 48.56810
Longitude 13.4230 E
Altitude 1,277 feet
400 yrds
bing




Observation
Simulation
Discharge (m3s-1)
1200
1000
800
600
400
200
0
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984

Project size

Black Sea Project: 640,000 files

Area: 2M Km2

Subbasins: 12,982

HRUs: 89,202

Approximate time for a 30-year simulation run 27 hours

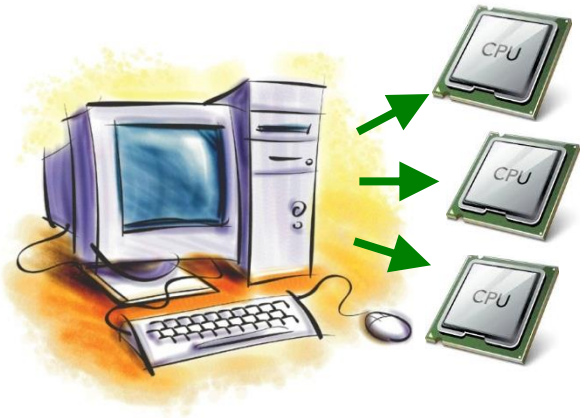
European Project:

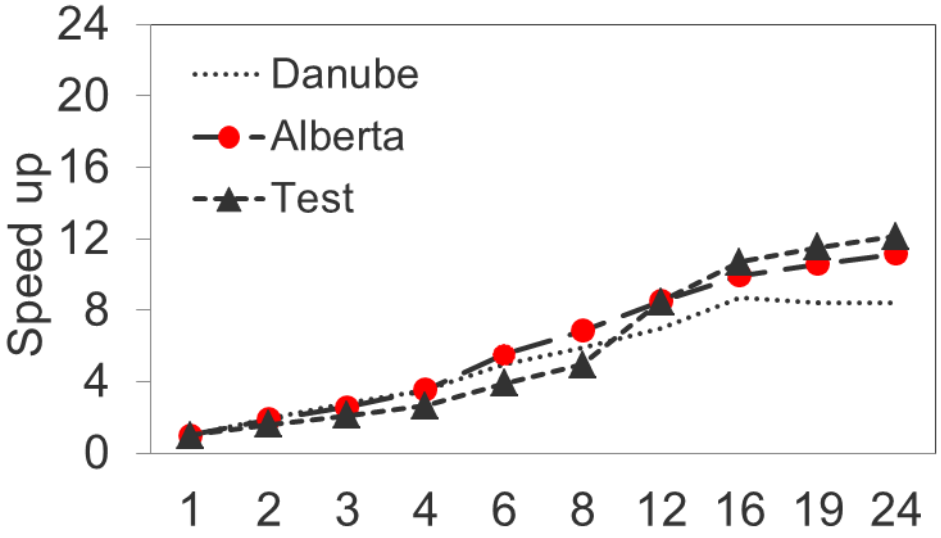
Area: 10 M Km2

Subbasins: 8,952

HRUs: 60,021

Parallel Processing





1 iteration of 200 simulation

(4 blocks of 50 worker node)

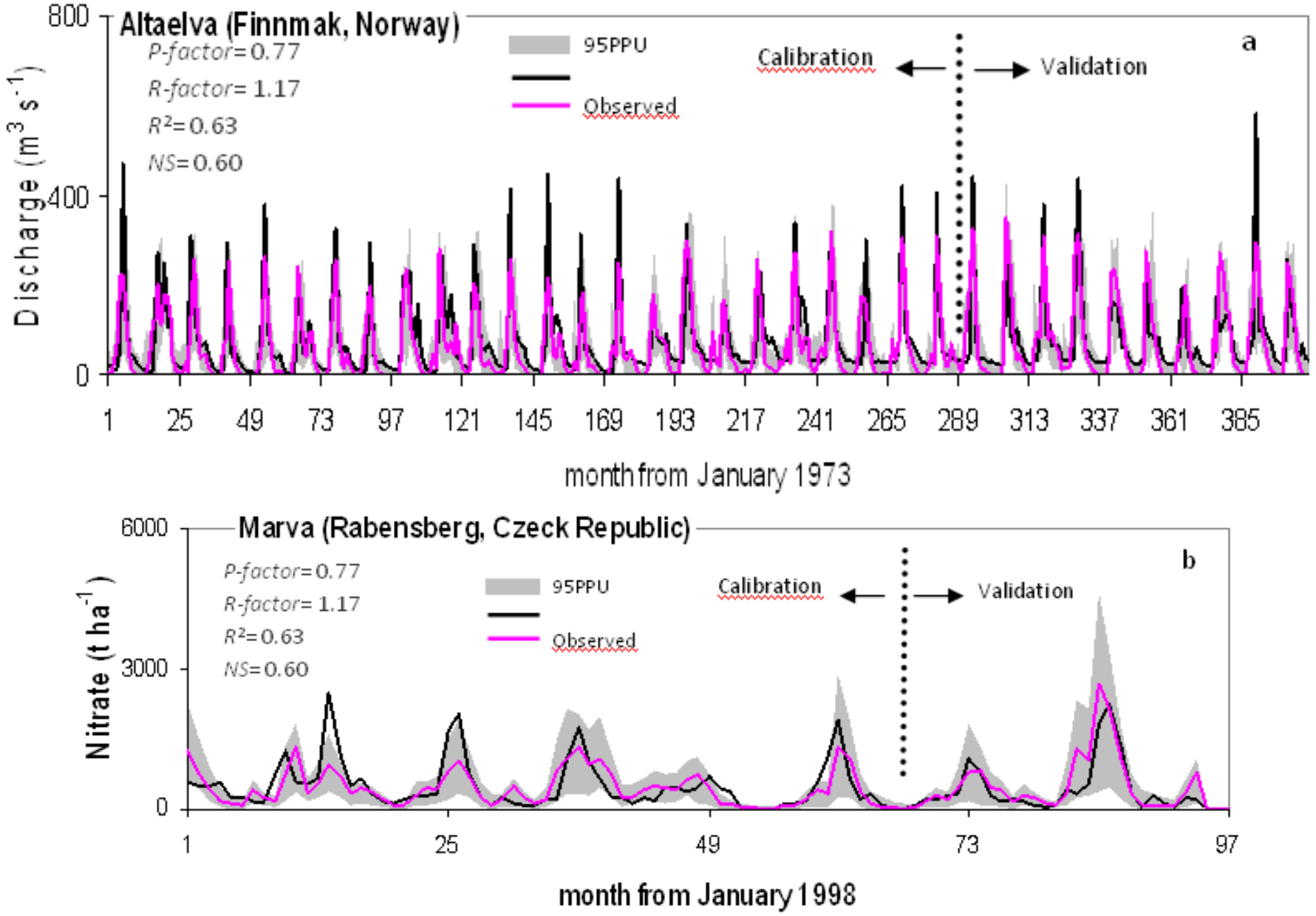
→ 2 weeks

Instead of 7.5 months!

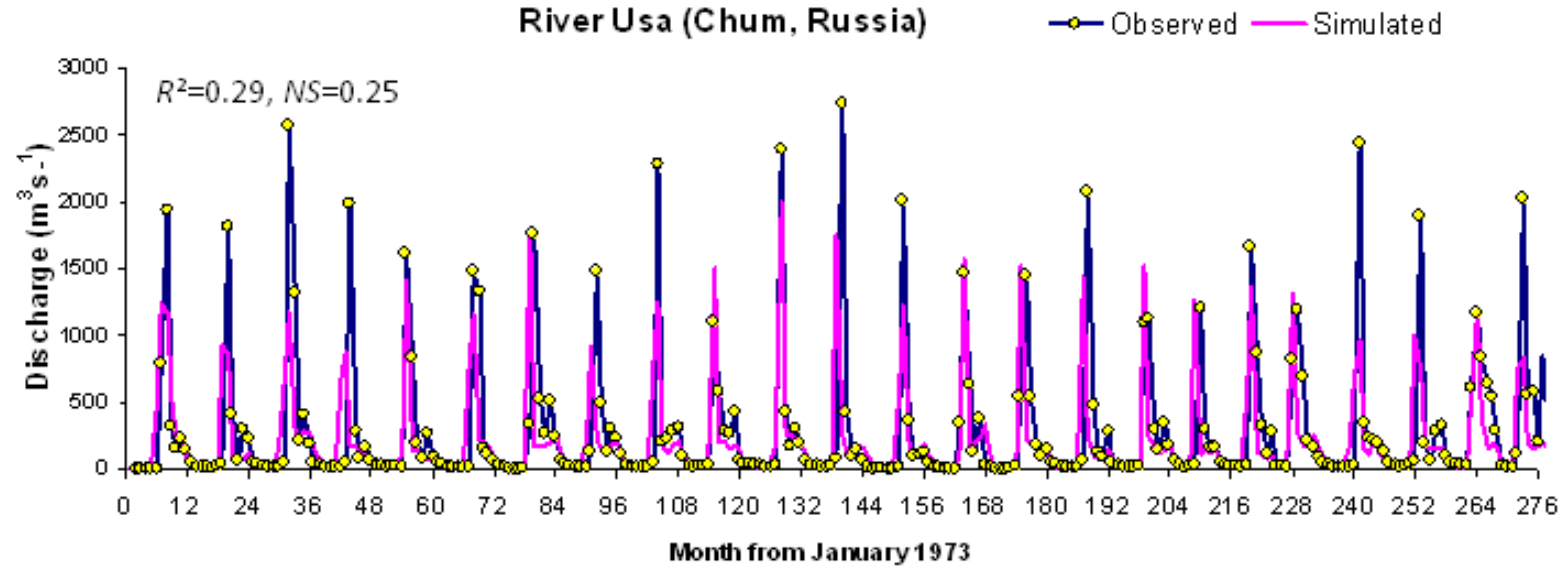
D. Gorgan, V. Bacu, D. Mihon, D. Rodila, K. Abbaspour, and E. Rouholahnejad, Grid based calibration of SWAT hydrological model, **Natura l Hazards and Earth System Science** , 2012.

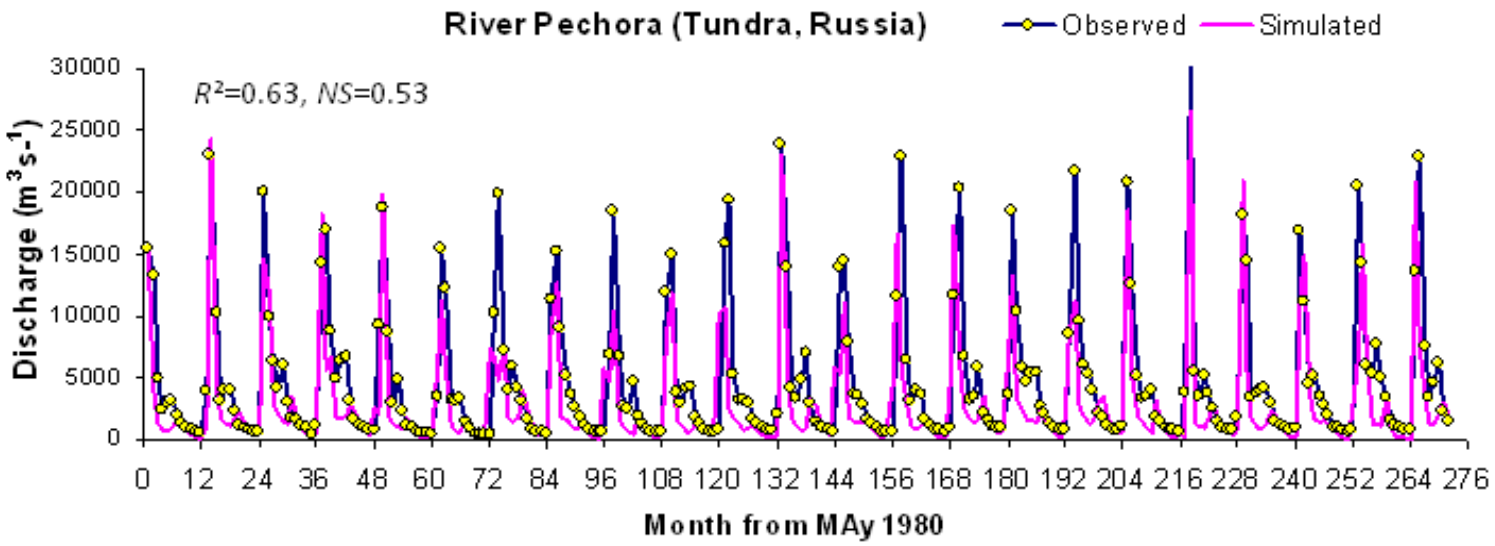
E. Rouholahnejad, K.C. Abbaspour, M. Vejdani, R. Srinivasan, R. Schulin, A. Lehmann: A parallelization framework for calibration of hydrological models , **Environmental Modelling and Software**, 2011.

Calibration/Validation

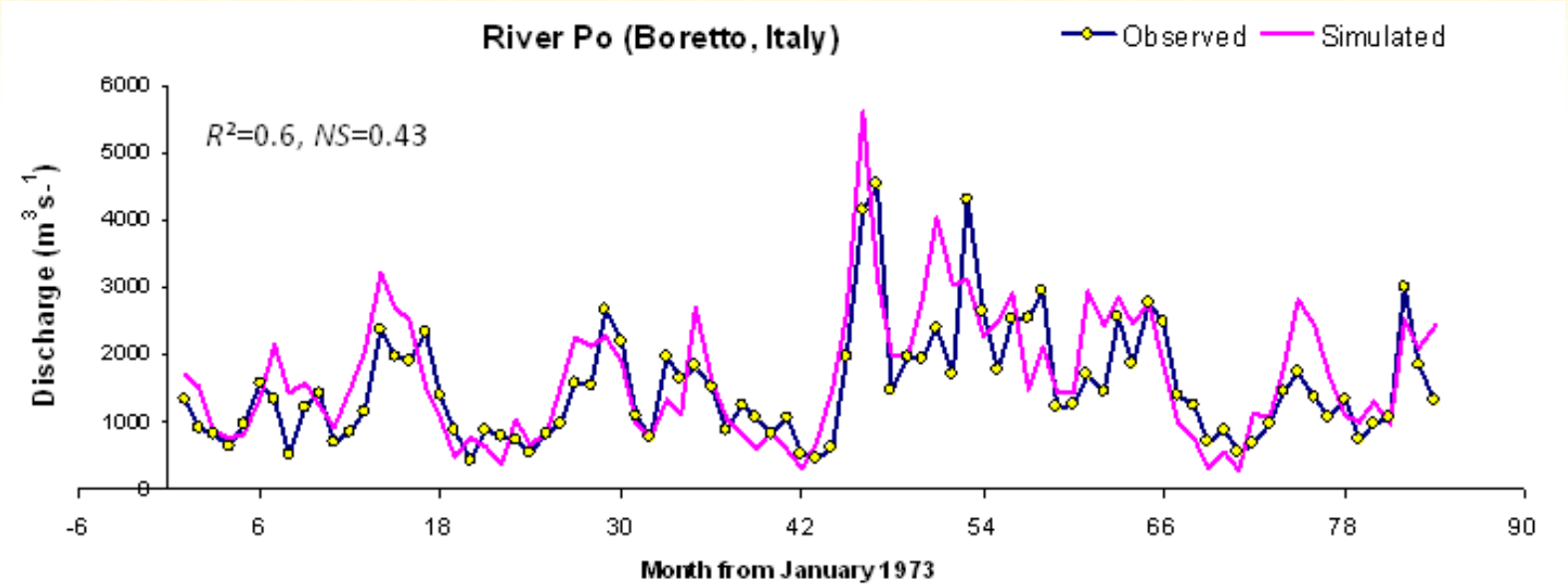


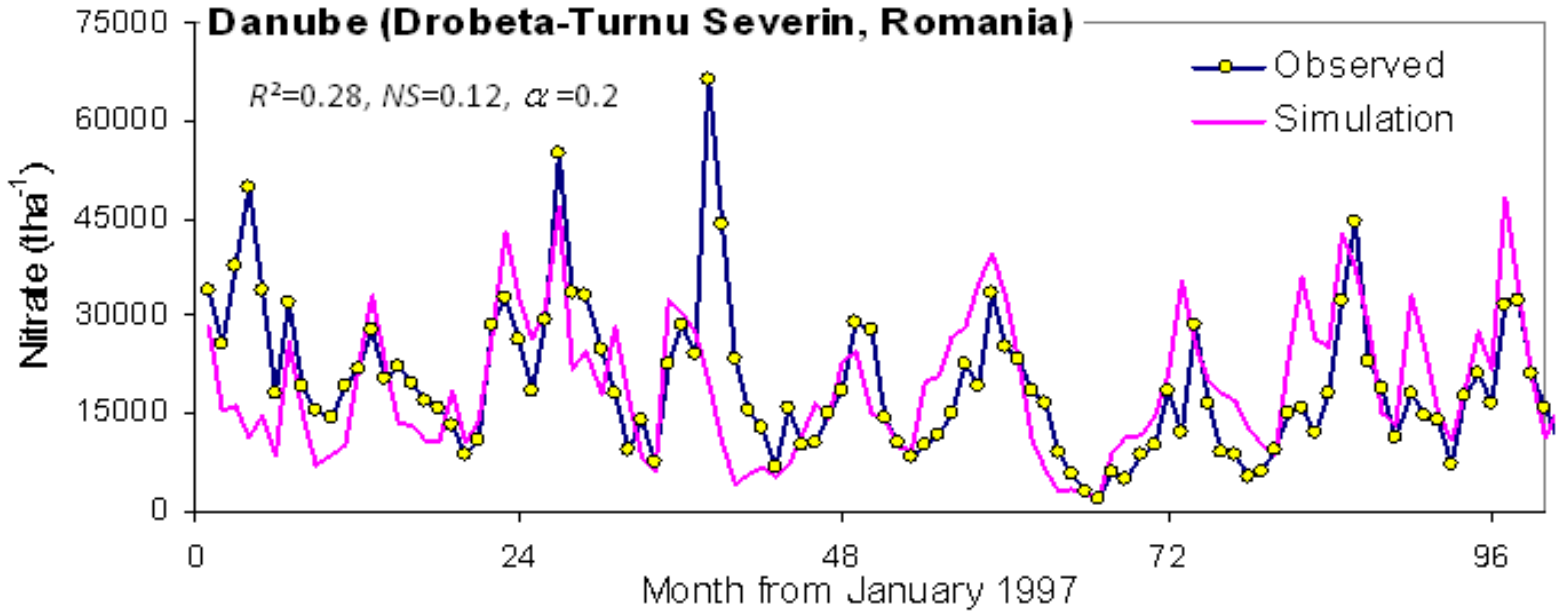
Discharge Calibration Results



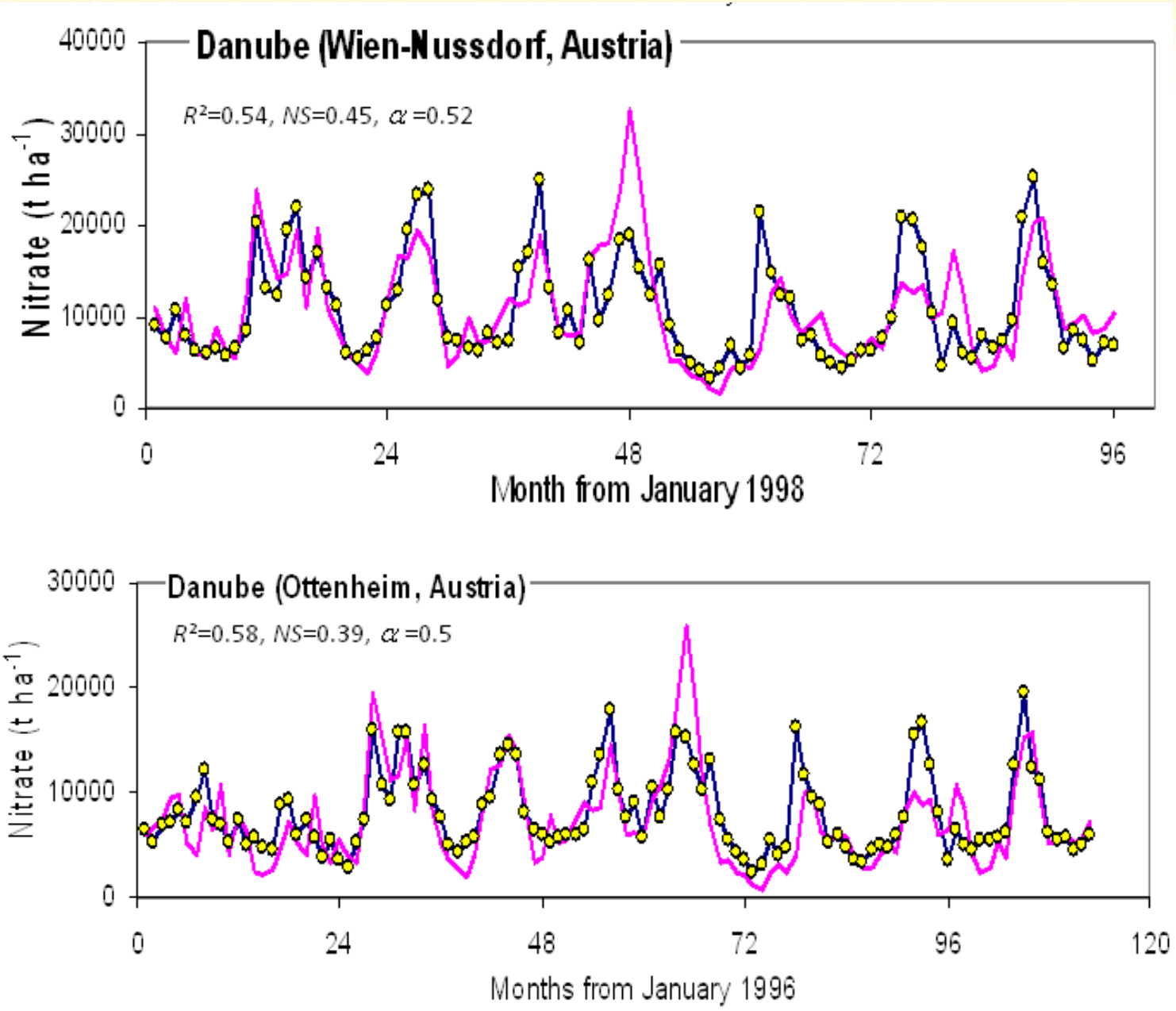


Discharge Calibration Results

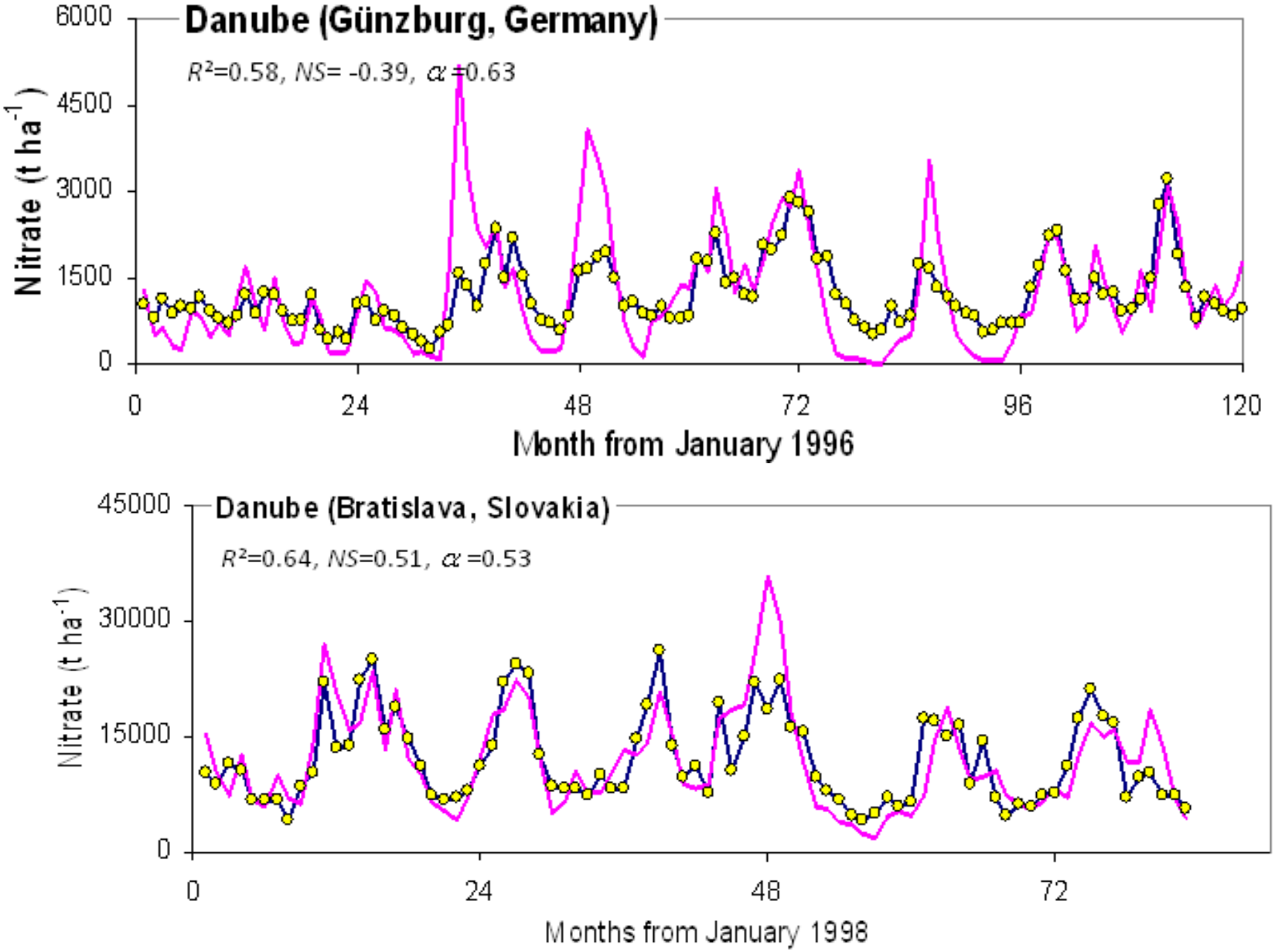




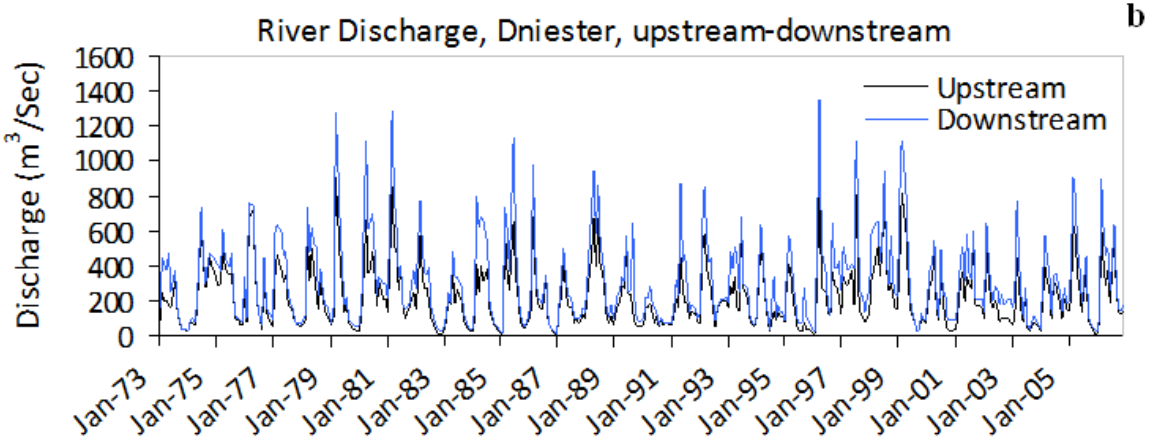
Discharge Calibration Results

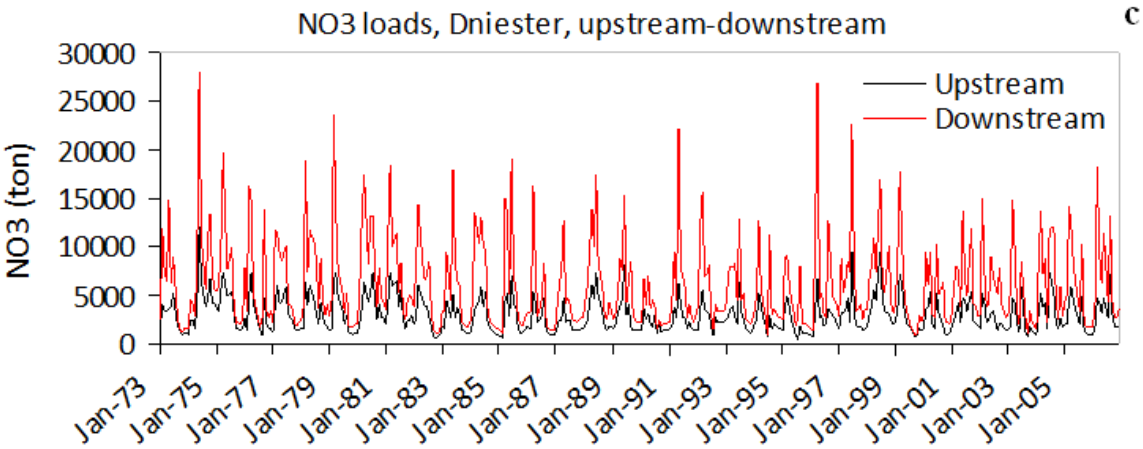


Discharge Calibration Results

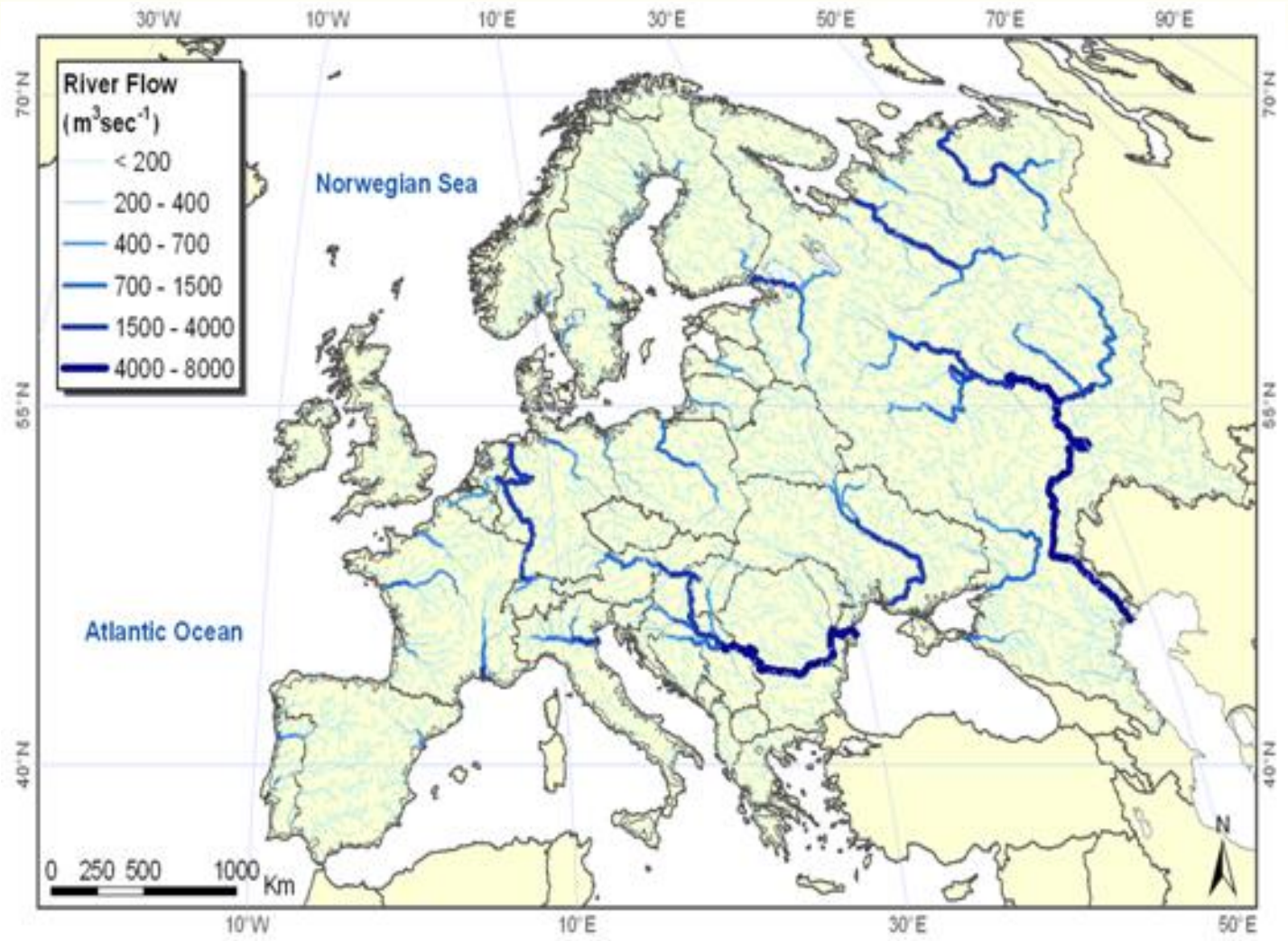



a
Dniestrovsky Reservoir
Dnieper
Dniester
Ukraine
Prut
Dubossary Reservoir
Moldova
Romania

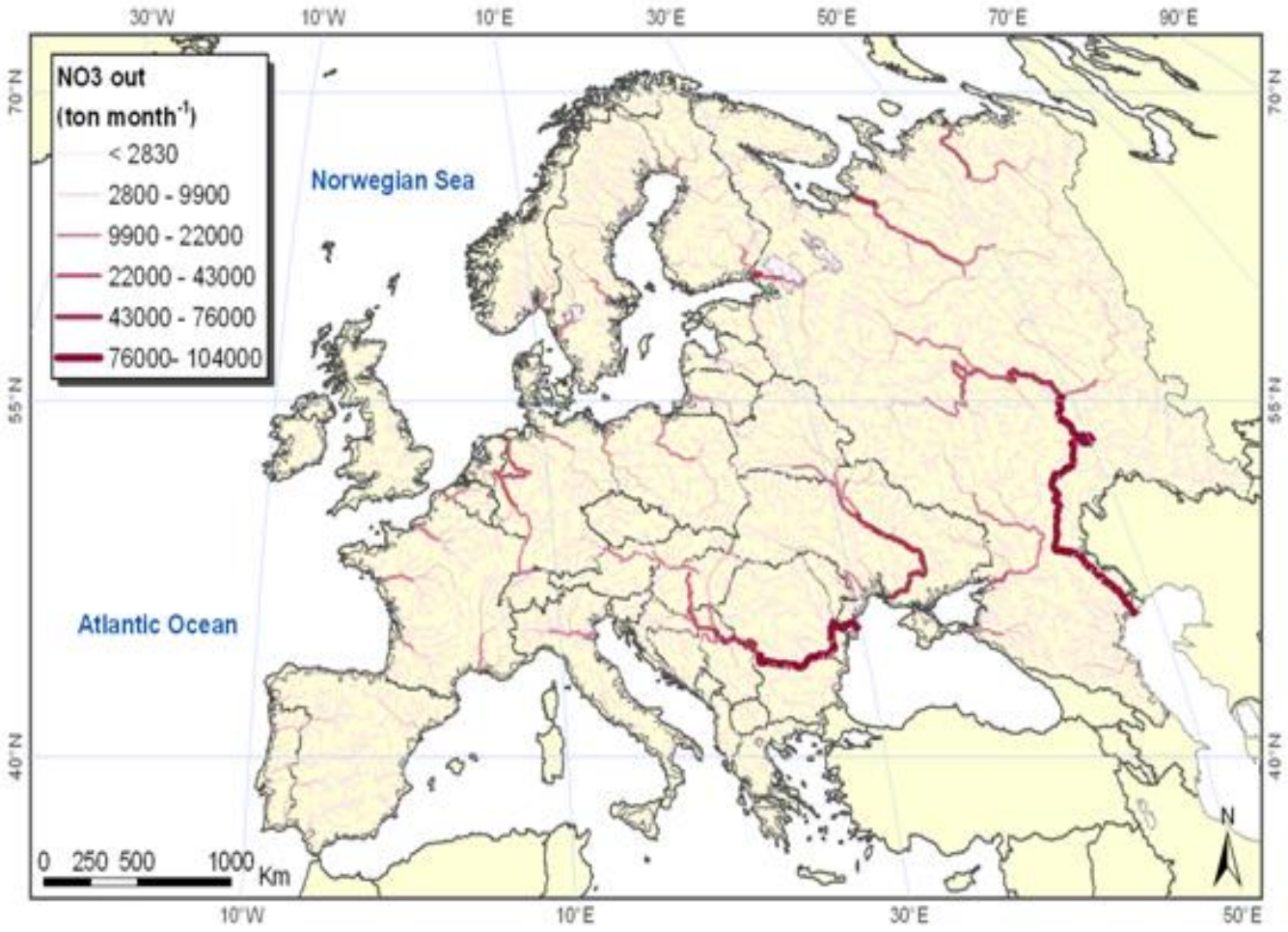

b
River Discharge, Dniester, upstream-downstream
Discharge (m3/Sec)
1600
1400
1200
1000
800
600
400
200
0
Upstream
Downstream
Jan-73
Jan-75
Jan-77
Jan-79
Jan-81
Jan-83
Jan-85
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05


c
NO3 loads, Dniester, upstream-downstream
NO3 (ton)
30000
25000
20000
15000
10000
5000
0
Upstream
Downstream
Jan-73
Jan-75
Jan-77
Jan-79
Jan-81
Jan-83
Jan-85
Jan-87
Jan-89
Jan-91
Jan-93
Jan-95
Jan-97
Jan-99
Jan-01
Jan-03
Jan-05

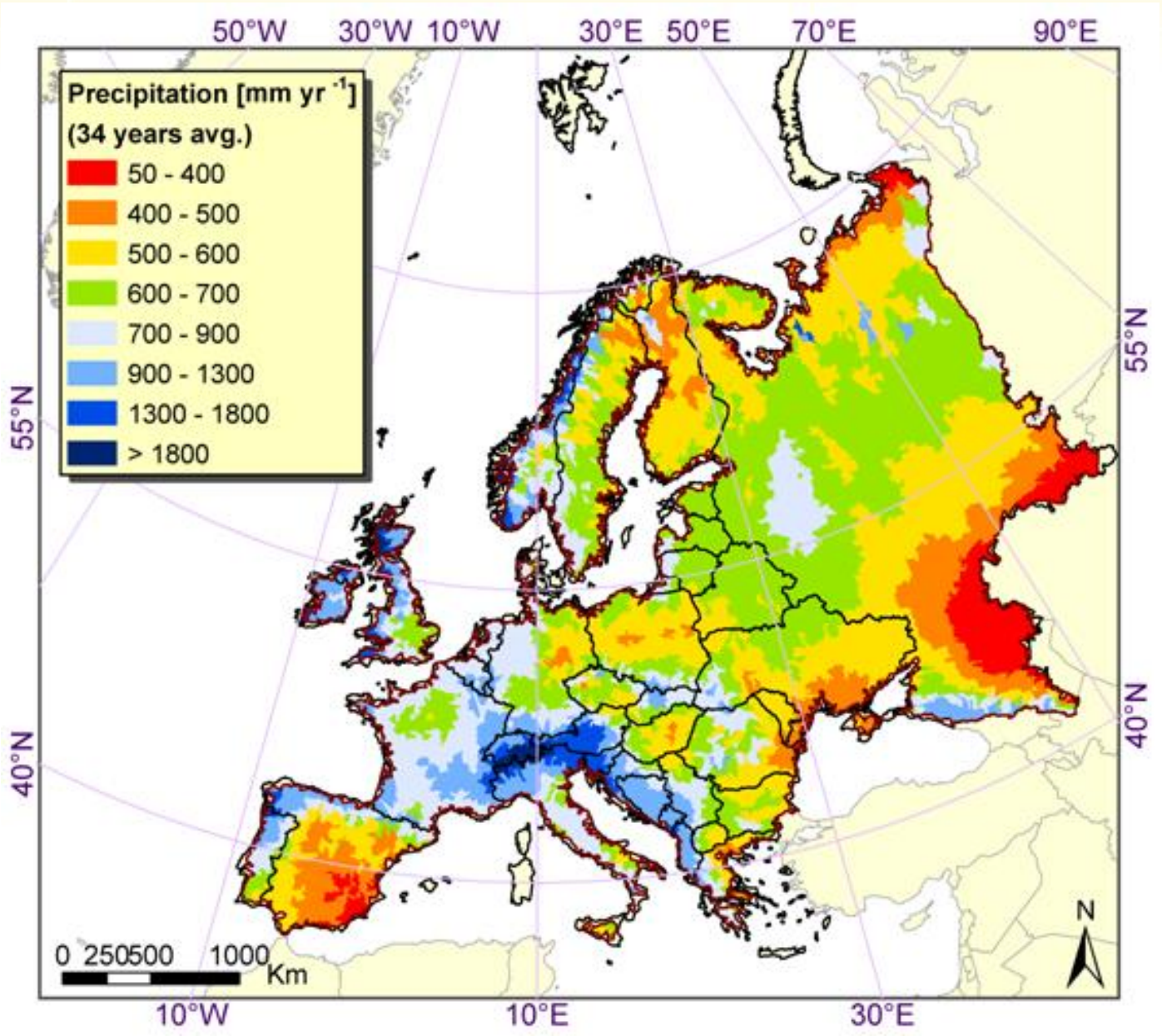
Analysis of Outputs



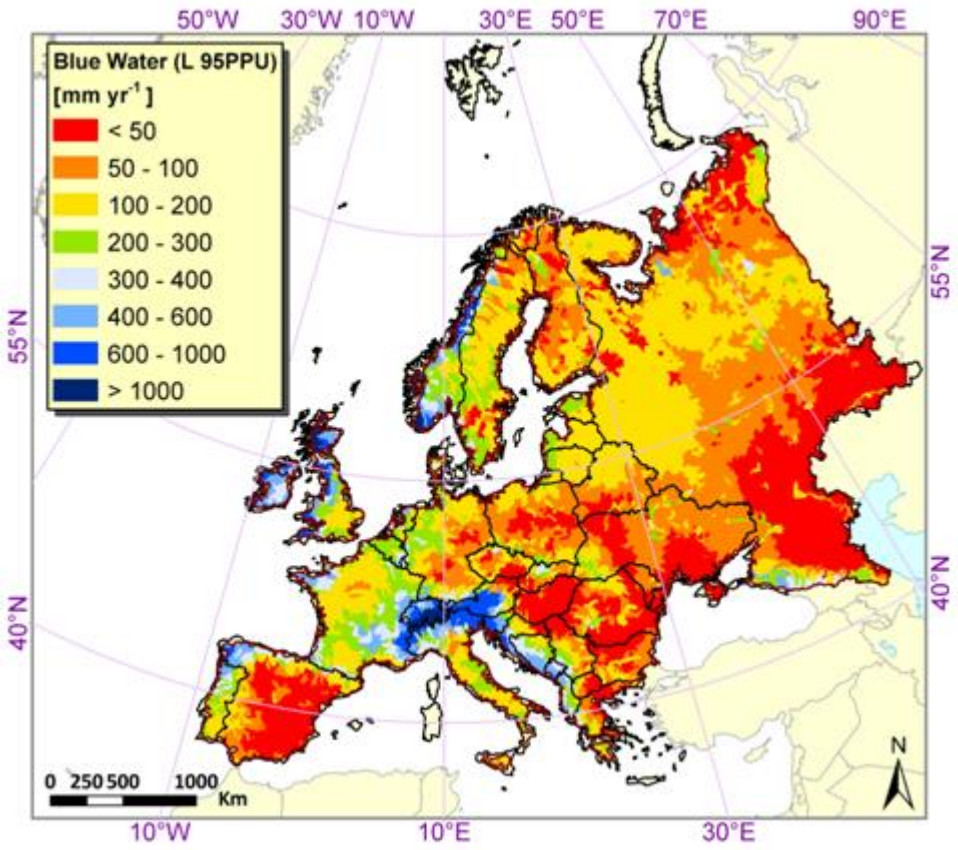
Analysis of Outputs

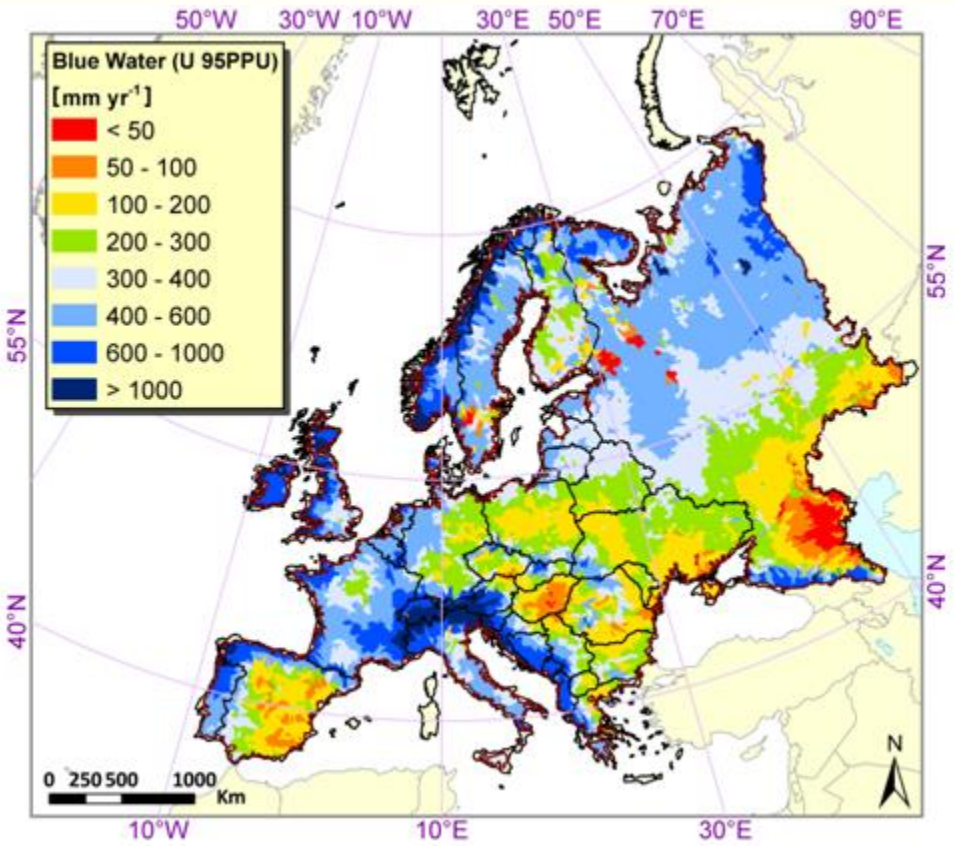


Analysis of Outputs

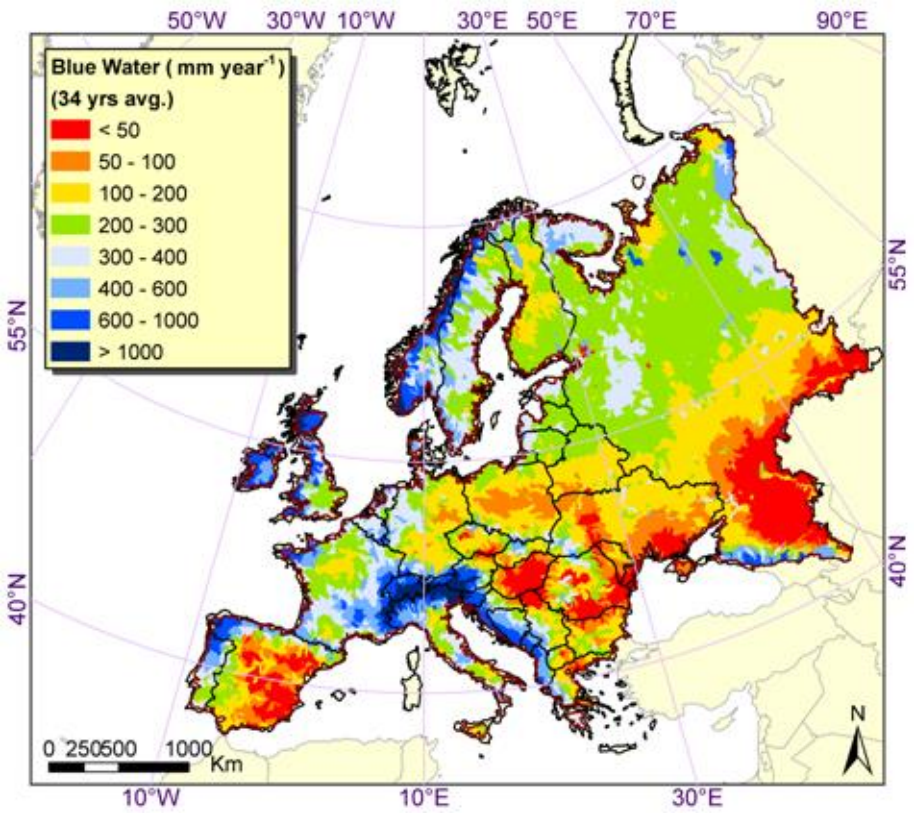


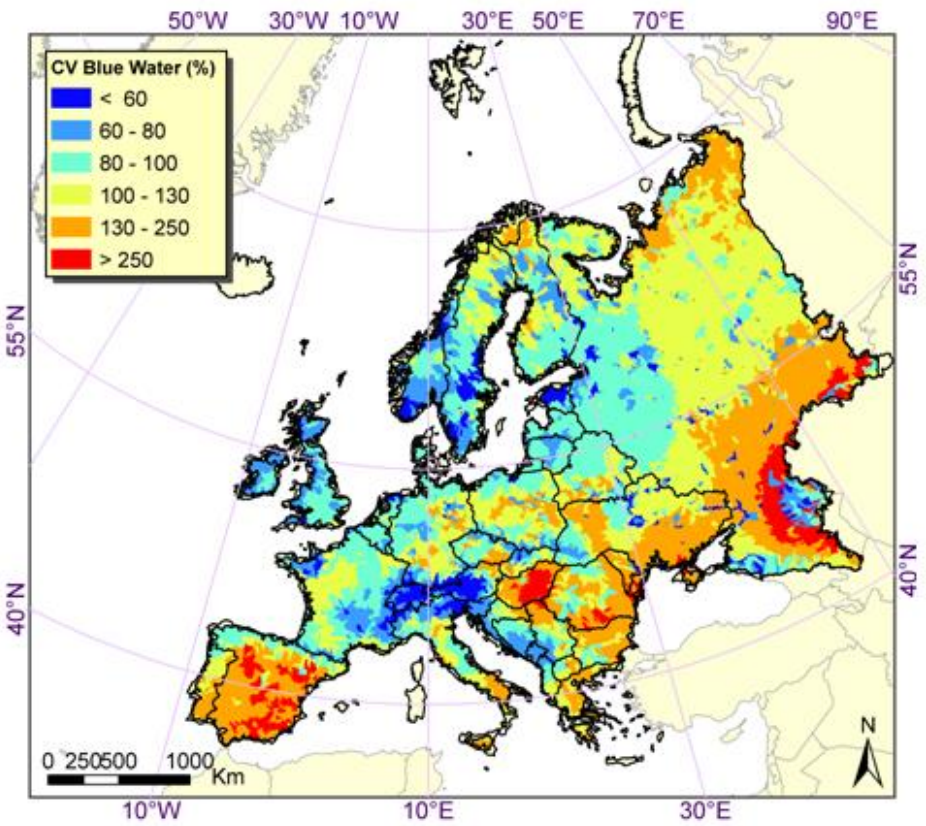
Blue Water


Blue Water (L 95PPU)
[mm yr-1]
< 50
50 - 100
100 - 200
200 - 300
300 - 400
400 - 600
600 - 1000
> 1000
50°W
30°W
10°W
30°E
50°E
70°E
90°E
55°N
40°N
10°W
10°E
30°E
0 250 500 1000
Km
N


Blue Water (U 95PPU)
[mm yr-1]
< 50
50 - 100
100 - 200
200 - 300
300 - 400
400 - 600
600 - 1000
> 1000
50°W
30°W
10°W
30°E
50°E
70°E
90°E
55°N
40°N
10°W
10°E
30°E
0 250 500 1000
Km
N

Blue Water


Blue Water (mm year-1)
(34 yrs avg.)
< 50
50 - 100
100 - 200
200 - 300
300 - 400
400 - 600
600 - 1000
> 1000
50°W 30°W 10°W 30°E 50°E 70°E 90°E
55°N
40°N
10°W 10°E 30°E
0 250500 1000 Km
N

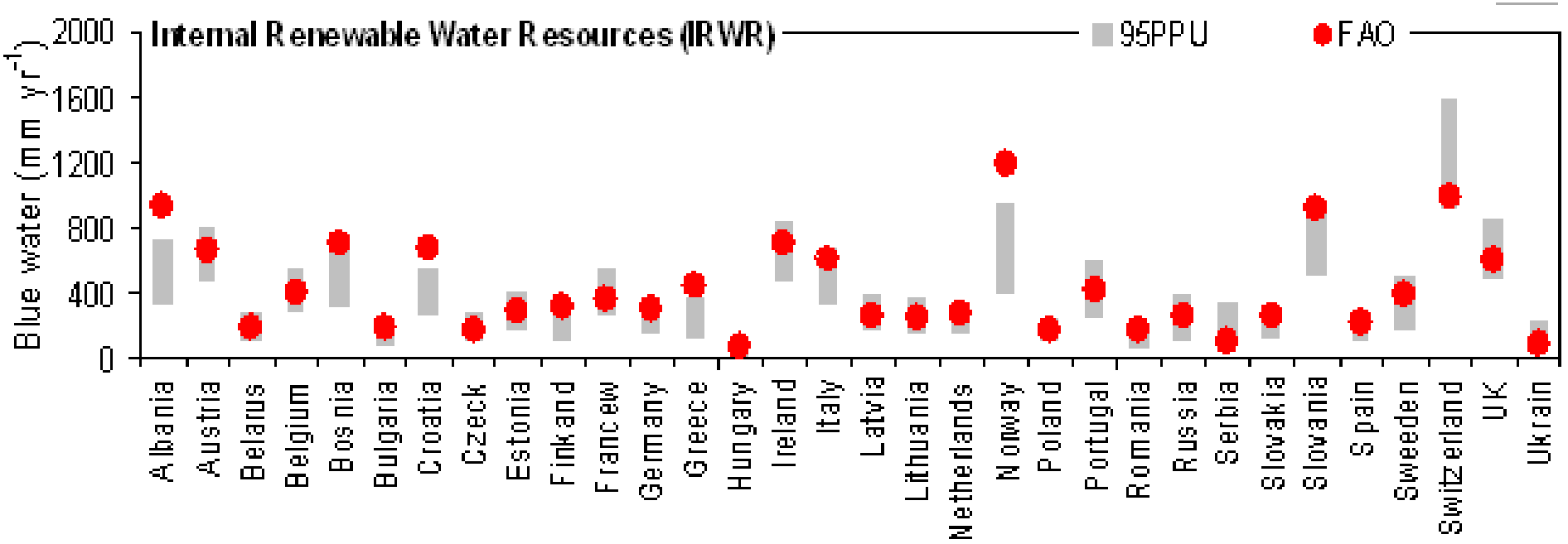

CV Blue Water (%)
< 60
60 - 80
80 - 100
100 - 130
130 - 250
> 250
50°W 30°W 10°W 30°E 50°E 70°E 90°E
55°N
40°N
10°W 10°E 30°E
0 250500 1000 Km
N

Analysis of Outputs

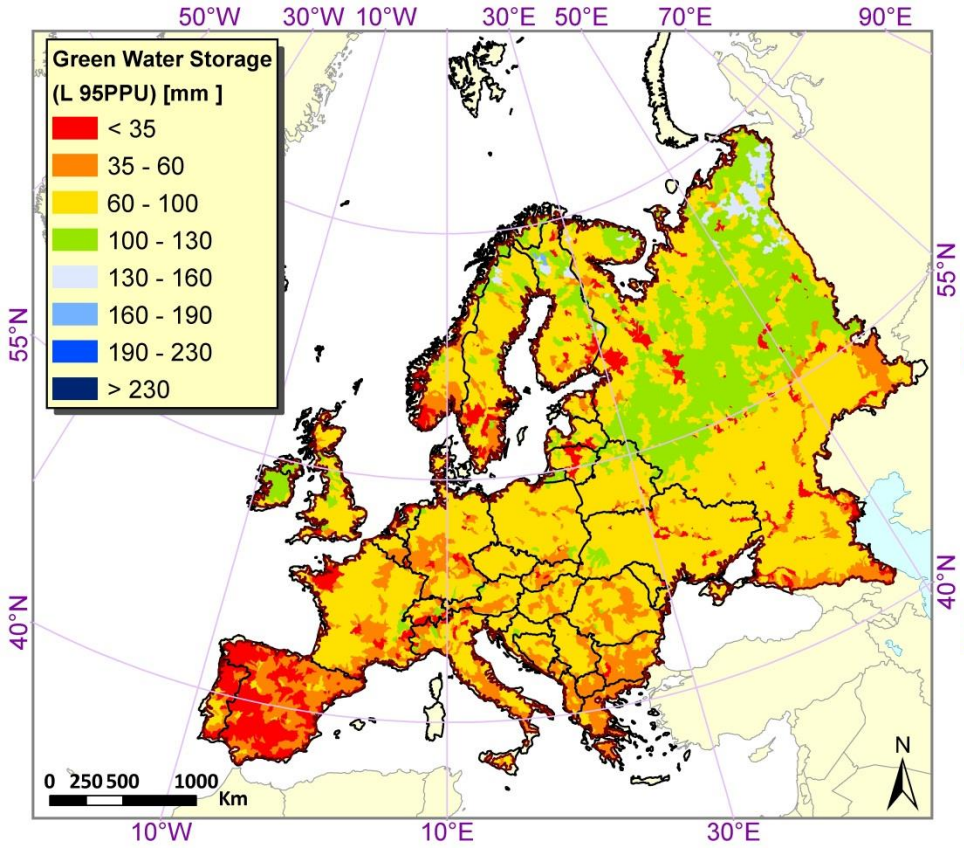
eawag aquatic research

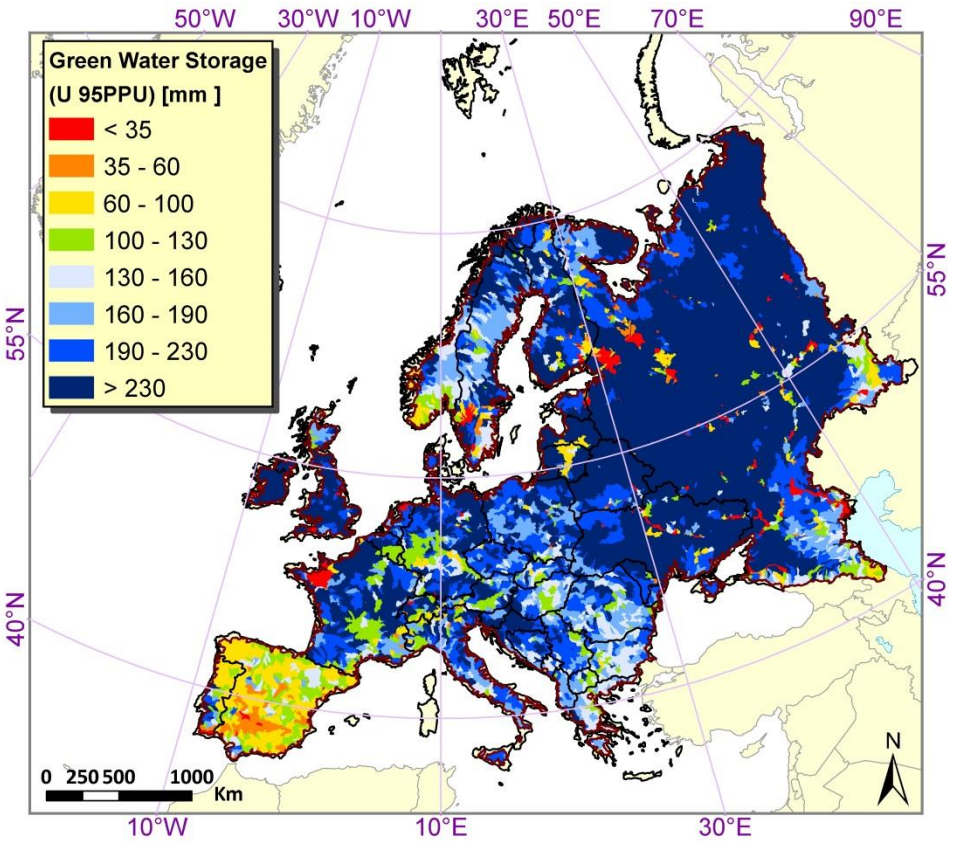
Country	Area (km^2)	Precipitation ($km^3\ yr^{-1}$)	Blue water flow ($km^3\ yr^{-1}$)	Greenwater storage (km^3)	Green water flow ($km^3\ yr^{-1}$)
Albania	28,750	29	9-21	17-91	10-12
Austria	83,870	95	39-67	64-267	36-42
Belarus	207,600	128	20-58	211-429	80-92
Belgium	30,530	27	8-17	24-84	13-15
Bosnia	51,210	54	16-35	45-113	27-32
Bulgaria	111,000	68	7-27	72-272	44-53
Croatia	56,590	58	14-32	42-71	23-27
Czeck	78,870	51	8-21	67-151	32-37
Denmark	43,090	34	3-6	9-22	3-4
Estonia	45,230	30	8-18	25-65	9-11
Finland	338,420	186	33-117	330-602	85-100
France	549,190	465	144-301	398-842	192-227
Germany	357,130	254	56-128	283-699	139-160
Greece	131,960	88	16-49	48-138	27-35
Hungary	93,030	55	1-11	69-158	40-47
Ireland	70,280	76	33-60	47-85	15-17
Spain	505,600	293	50-150	200-961	158-199
Sweeden	450,300	295	76-222	364-526	107-125
Switzerland	41,280	69	38-65	31-83	15-18
Ukrain	603,550	346	42-135	541-540	212-245
UK	243,610	257	119-209	208-433	82-98

Comparison

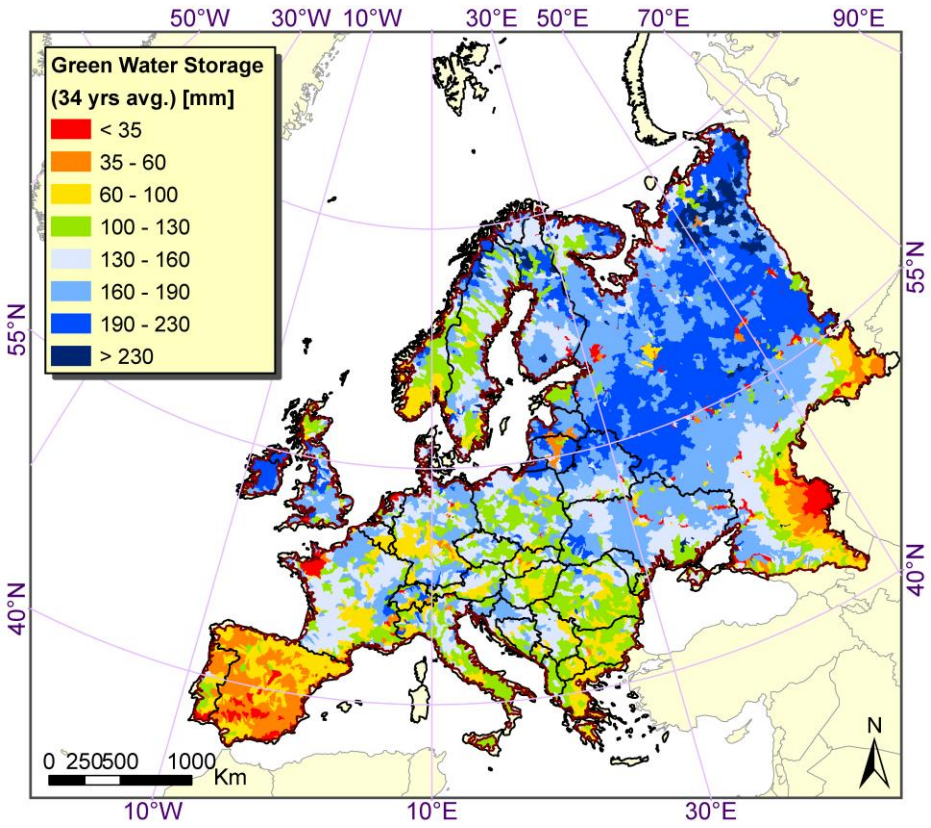

Internal Renewable Water Resources (IRWR)
95PPU
FAO
Blue water (mm yr-1)
2000
1600
1200
800
400
0
Albania
Austria
Belarus
Belgium
Bosnia
Bulgaria
Croatia
Czeck
Estonia
Finkand
Francew
Germany
Greece
Hungary
Ireland
Italy
Latvia
Lithuania
Netherlands
Norway
Poland
Portugal
Romania
Russia
Serbia
Slowakia
Slowania
Spain
Sweeden
Switzerland
UK
Ukrain

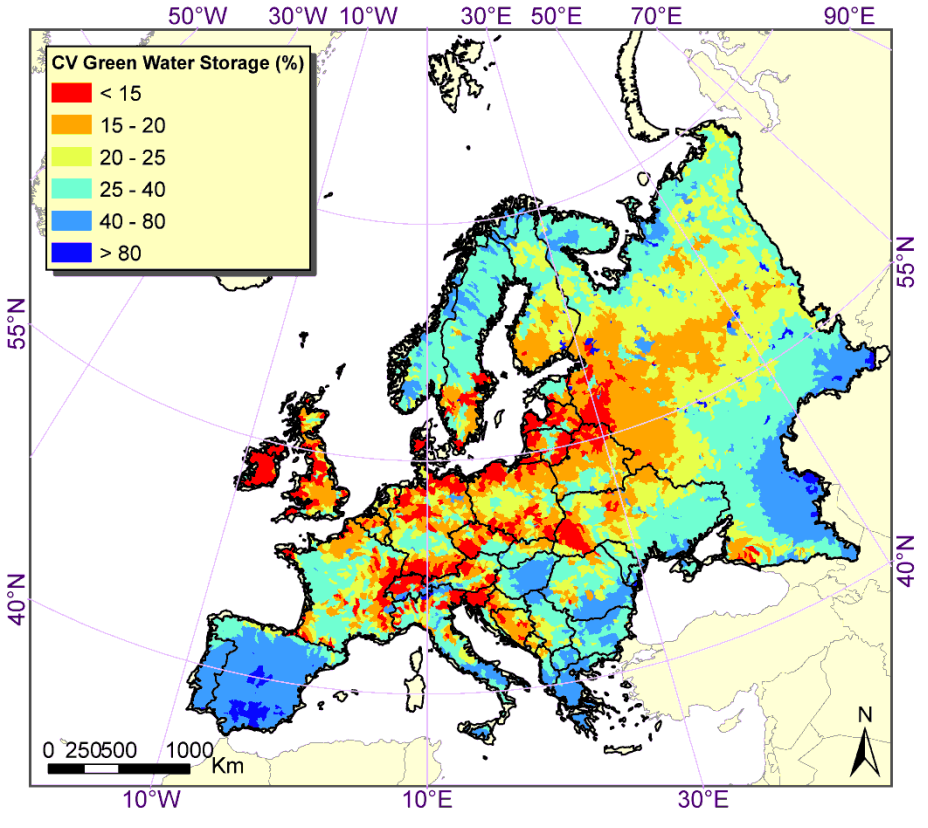
Green Water Storage



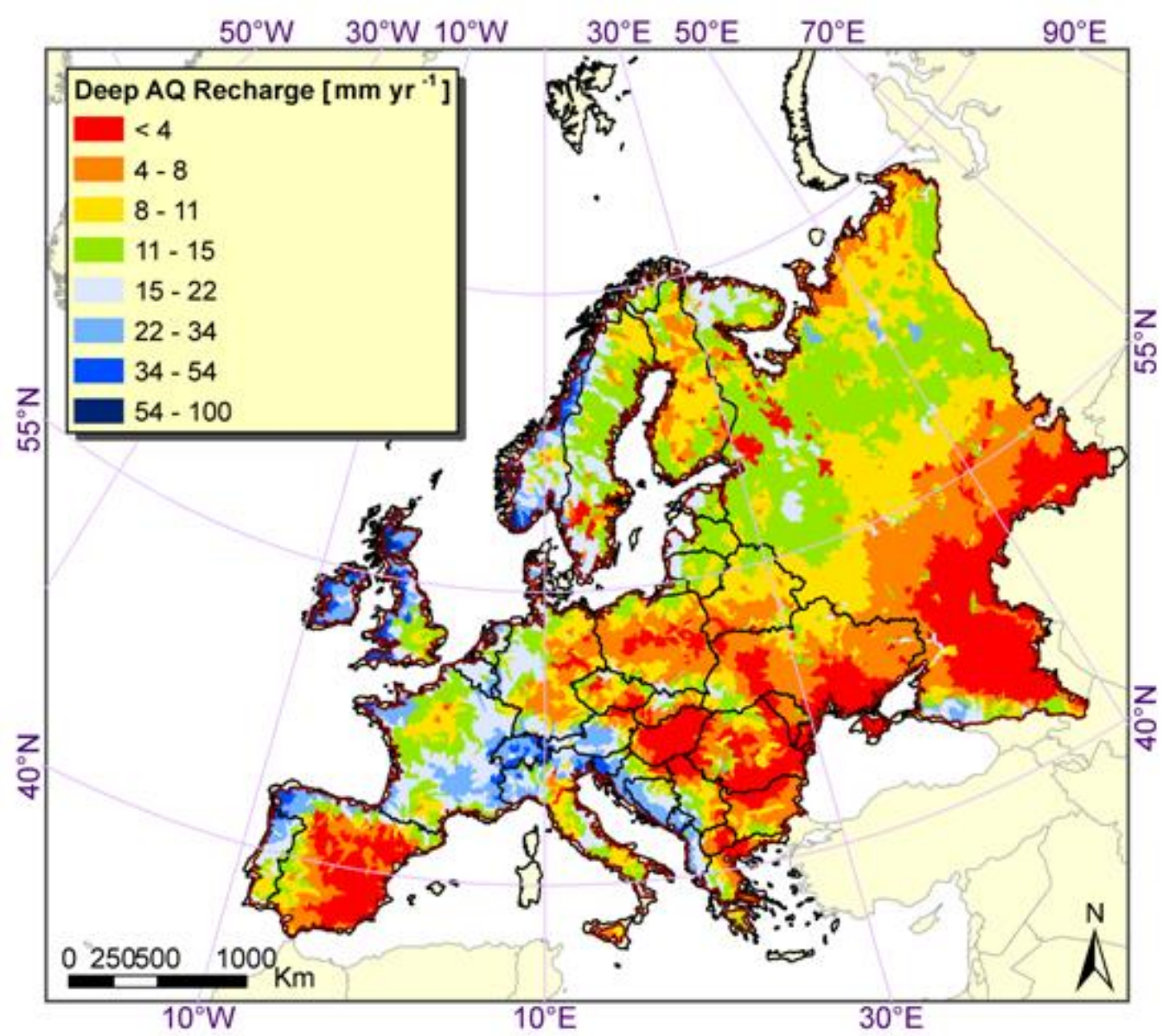


Green Water storage

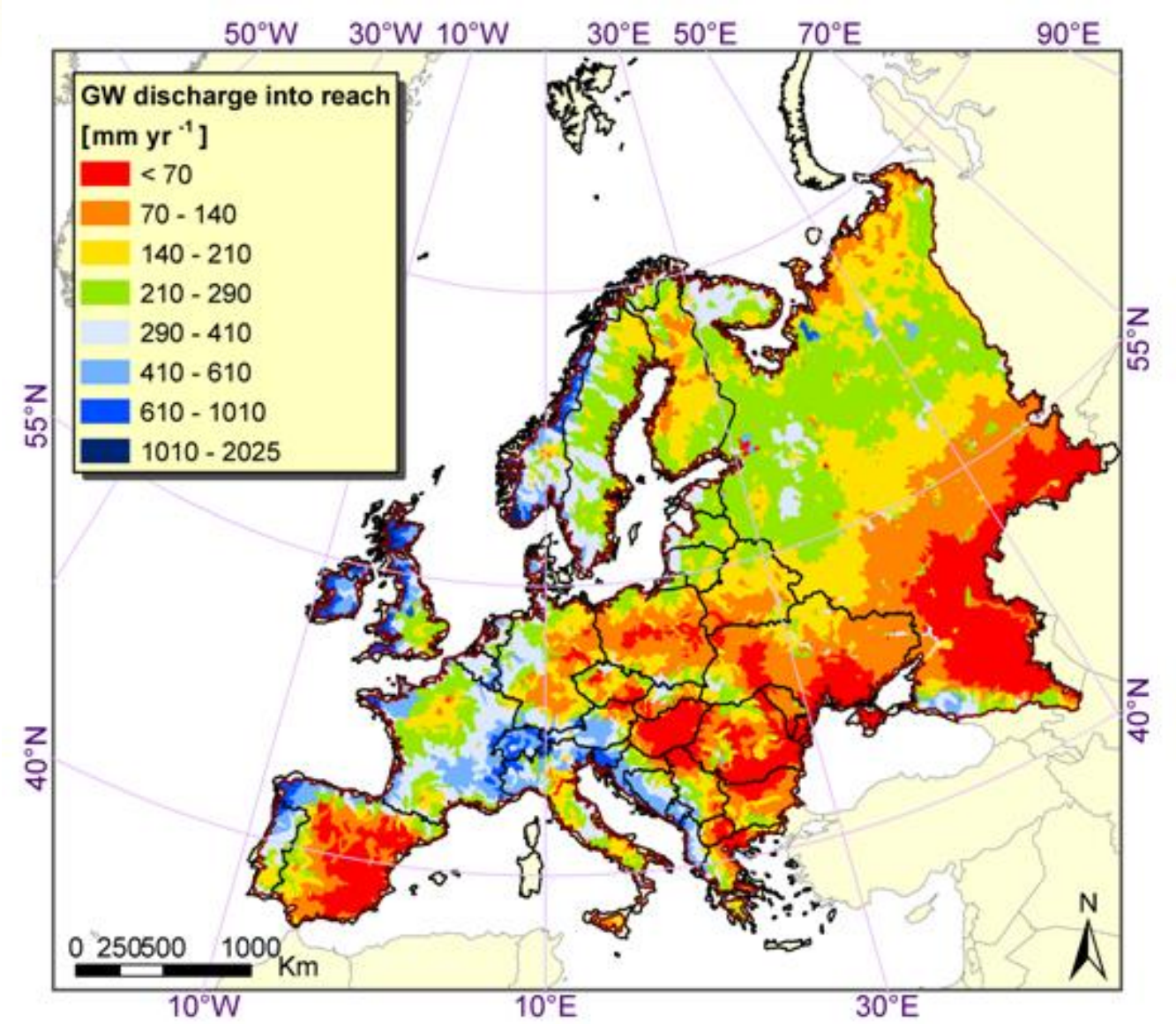




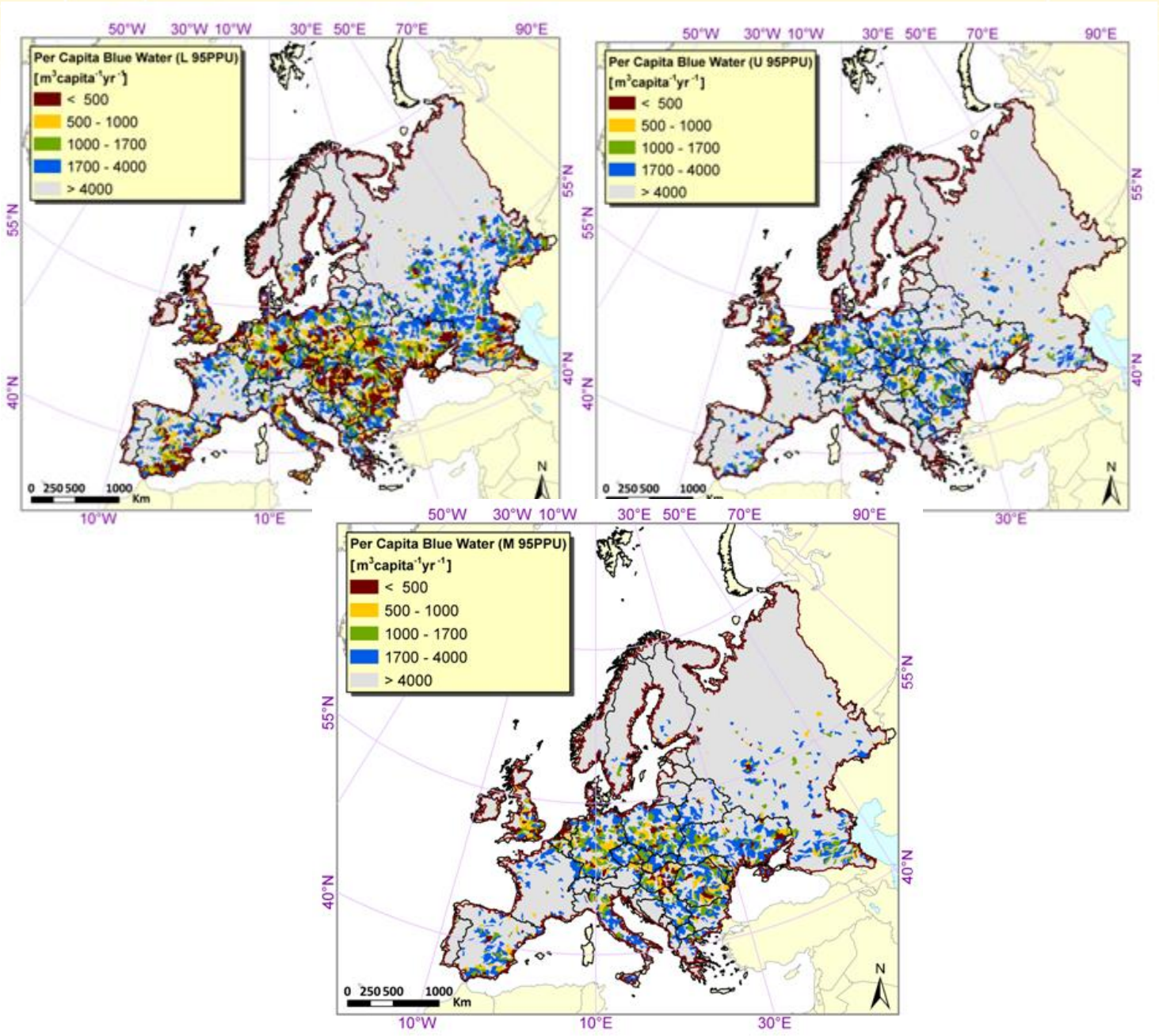
Deep Aquifer Recharge



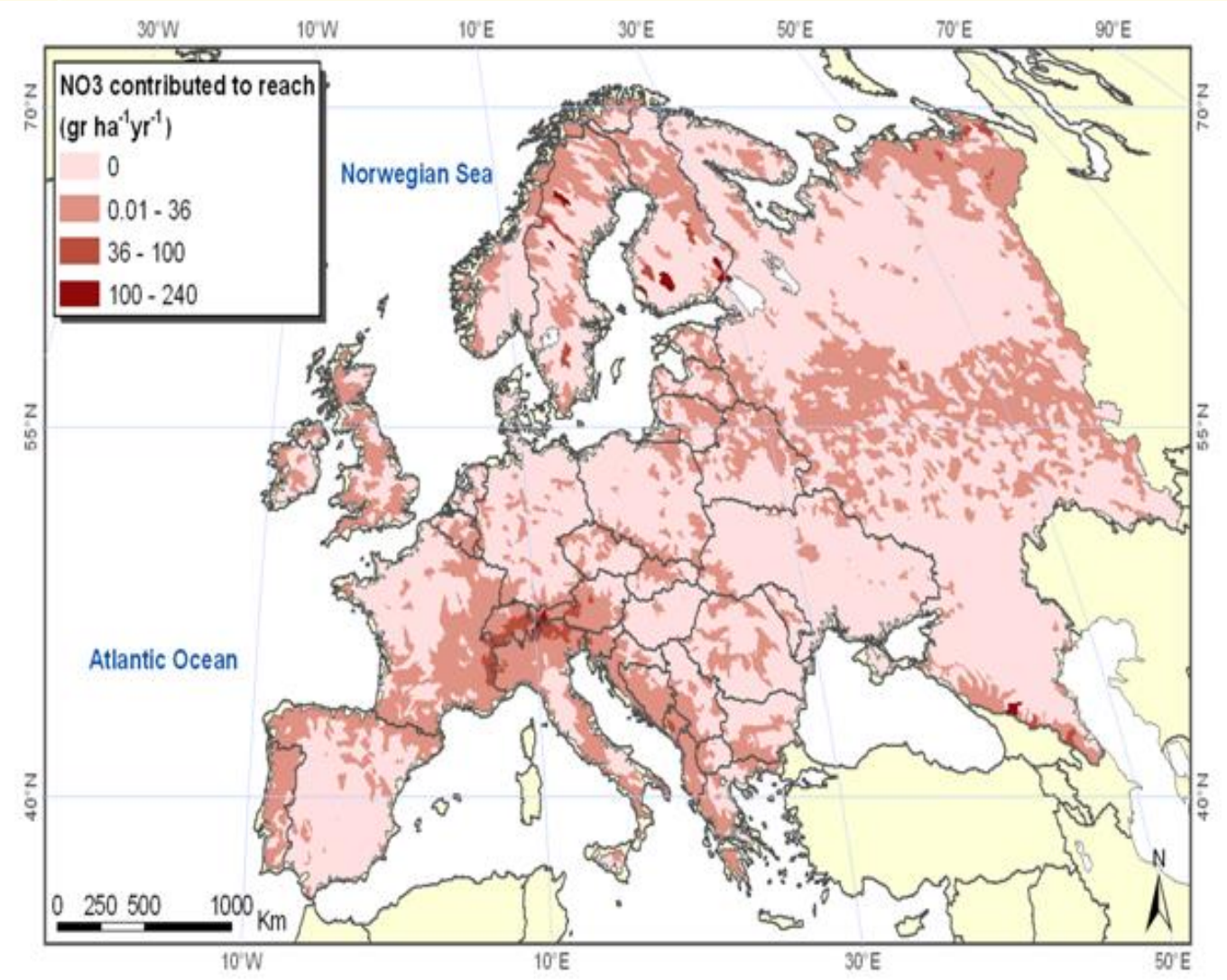
GW Discharge into Reach



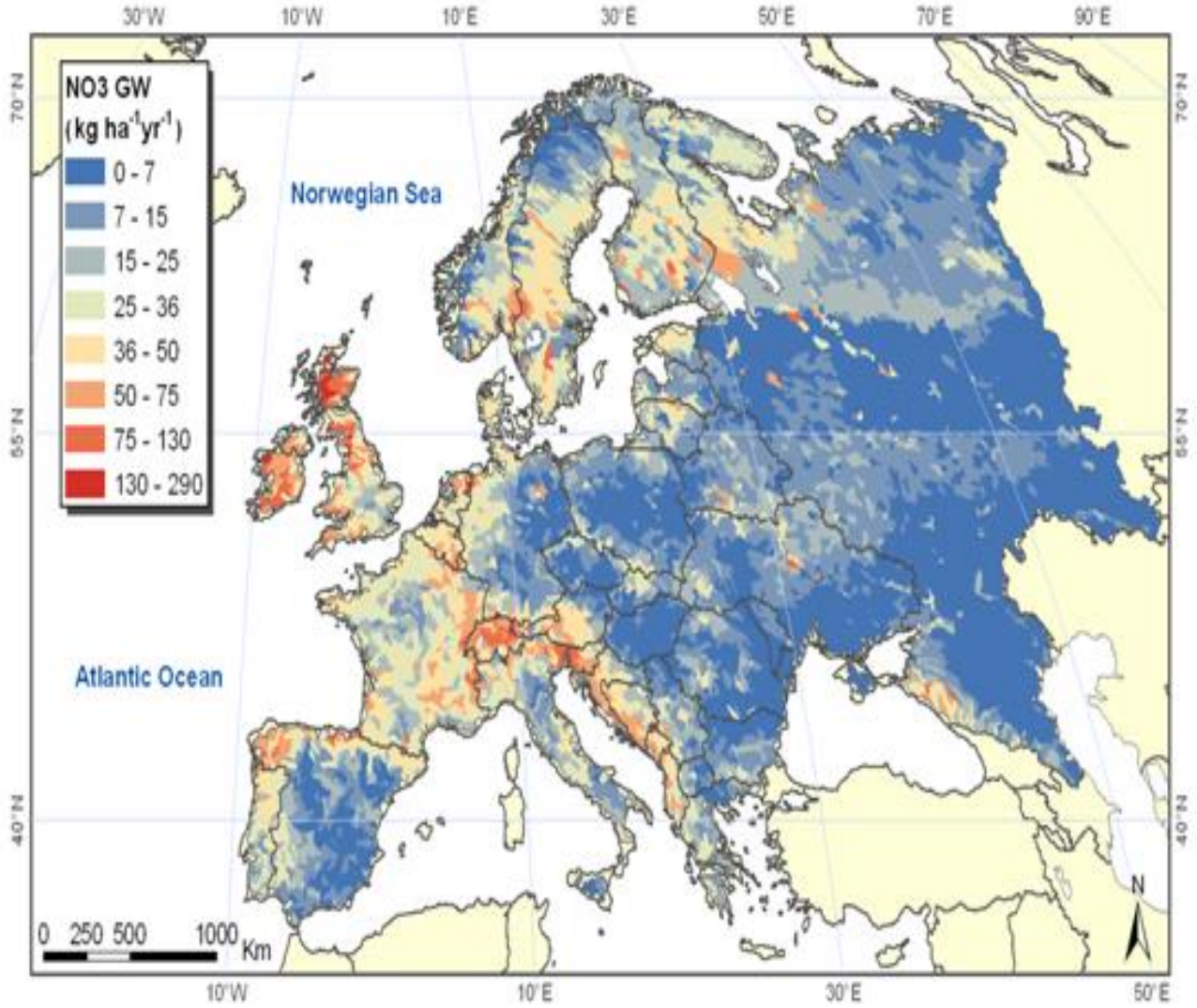
Per Capita Blue Water



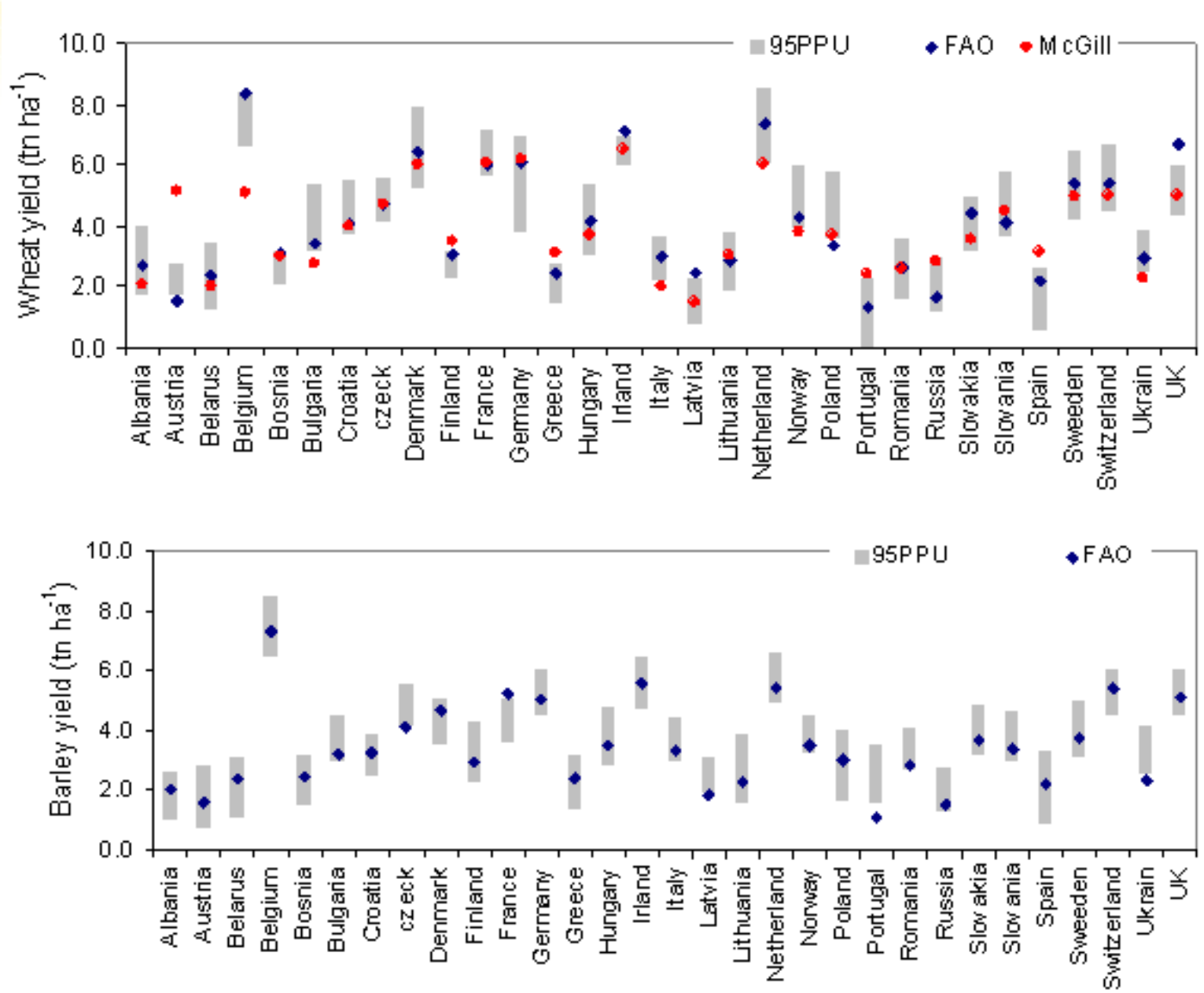
Nitrate Contribution to Reach



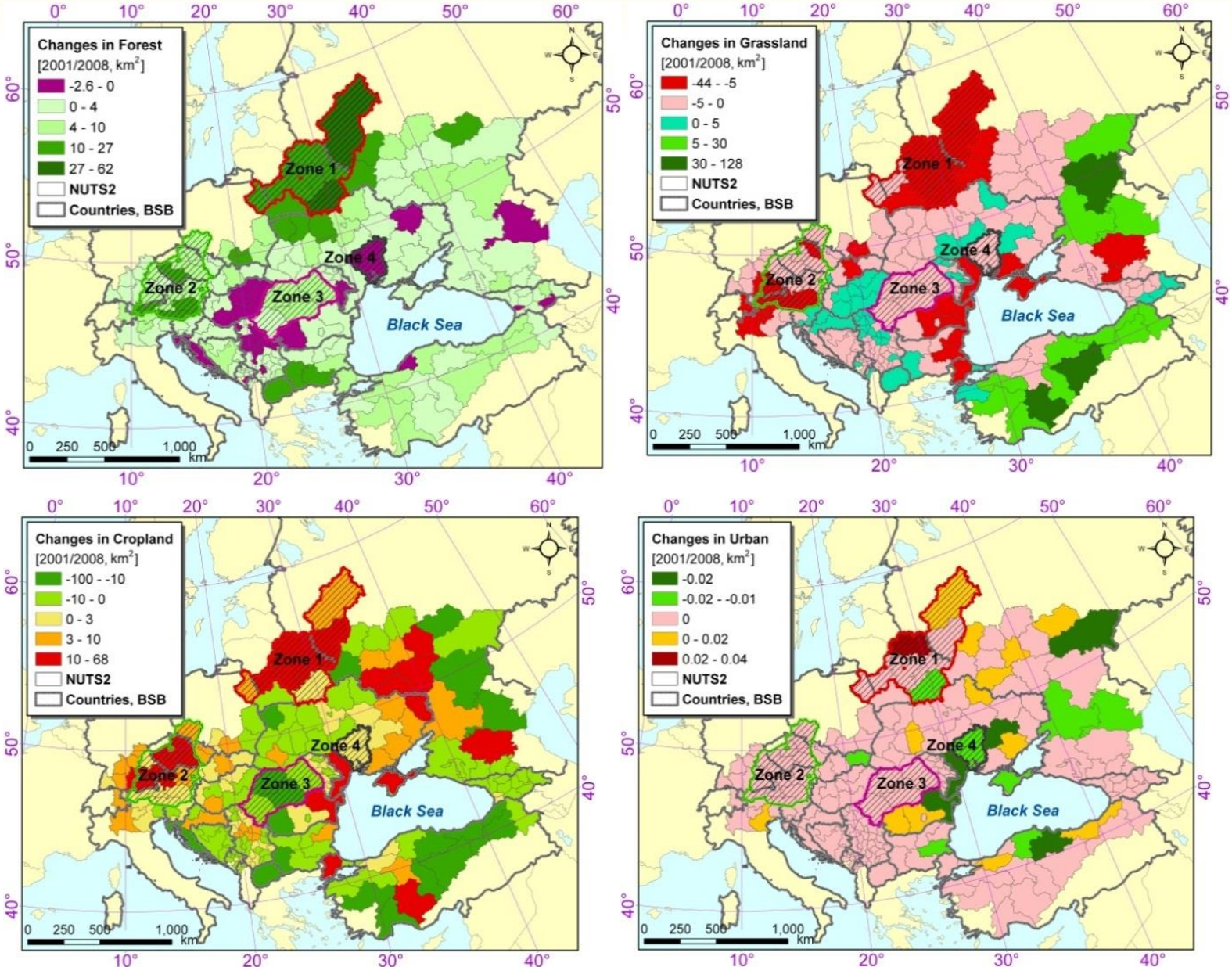
Nitrate Contribution to GW



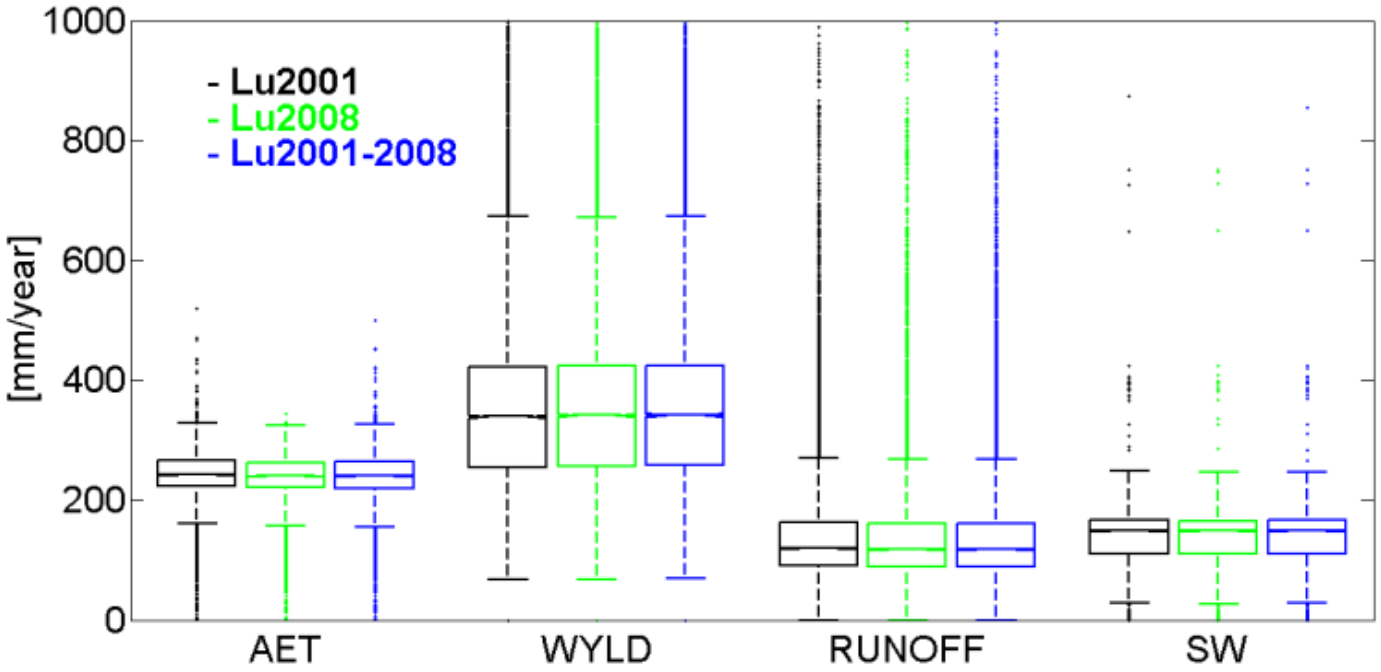
Comparison

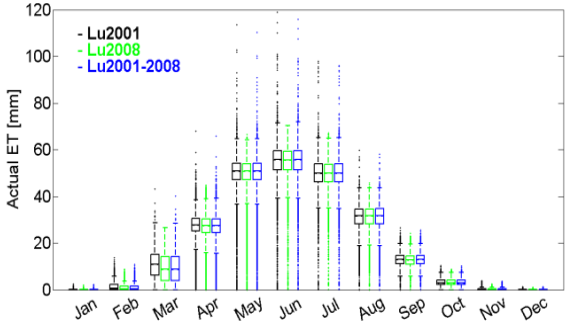

95PPU
FAO
McGill
Wheat yield (tn ha-1)
10.0
8.0
6.0
4.0
2.0
0.0
Albania
Austria
Belarus
Belgium
Bosnia
Bulgaria
Croatia
czeck
Denmark
Finland
France
Germany
Greece
Hungary
Irland
Italy
Latvia
Lithuania
Netherland
Norway
Poland
Portugal
Romania
Russia
Slowakia
Slovania
Spain
Sweeden
Switzerland
Ukrain
UK
95PPU
FAO
Barley yield (tn ha-1)
10.0
8.0
6.0
4.0
2.0
0.0
Albania
Austria
Belarus
Belgium
Bosnia
Bulgaria
Croatia
czeck
Denmark
Finland
France
Germany
Greece
Hungary
Irland
Italy
Latvia
Lithuania
Netherland
Norway
Poland
Portugal
Romania
Russia
Slowakia
Slovania
Spain
Sweeden
Switzerland
Ukrain
UK

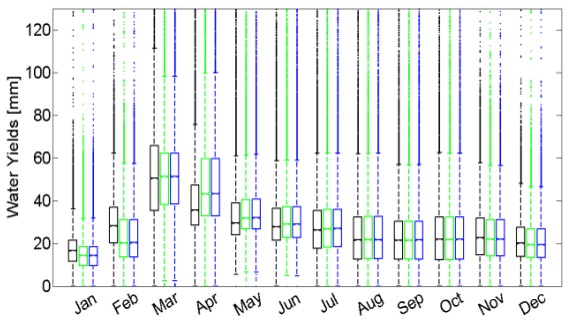
Landuse change, 2001 to 2008 (Metronomica)

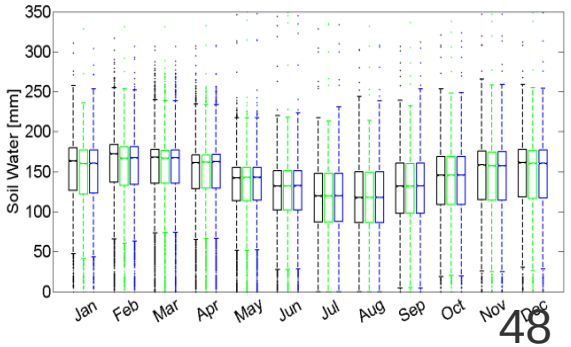


Water component change at watershed level





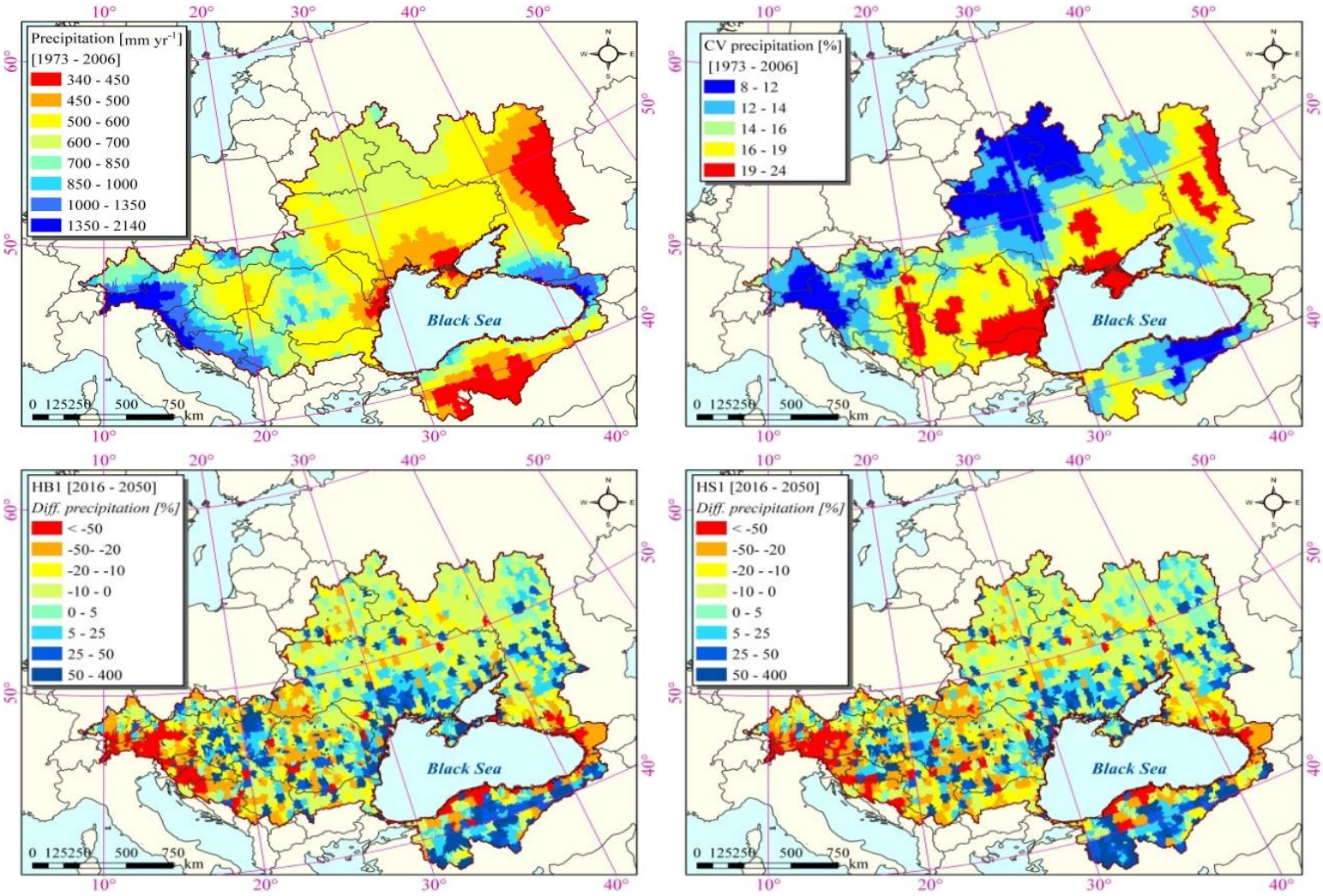




Future climate scenarios (precipitation)

Historic

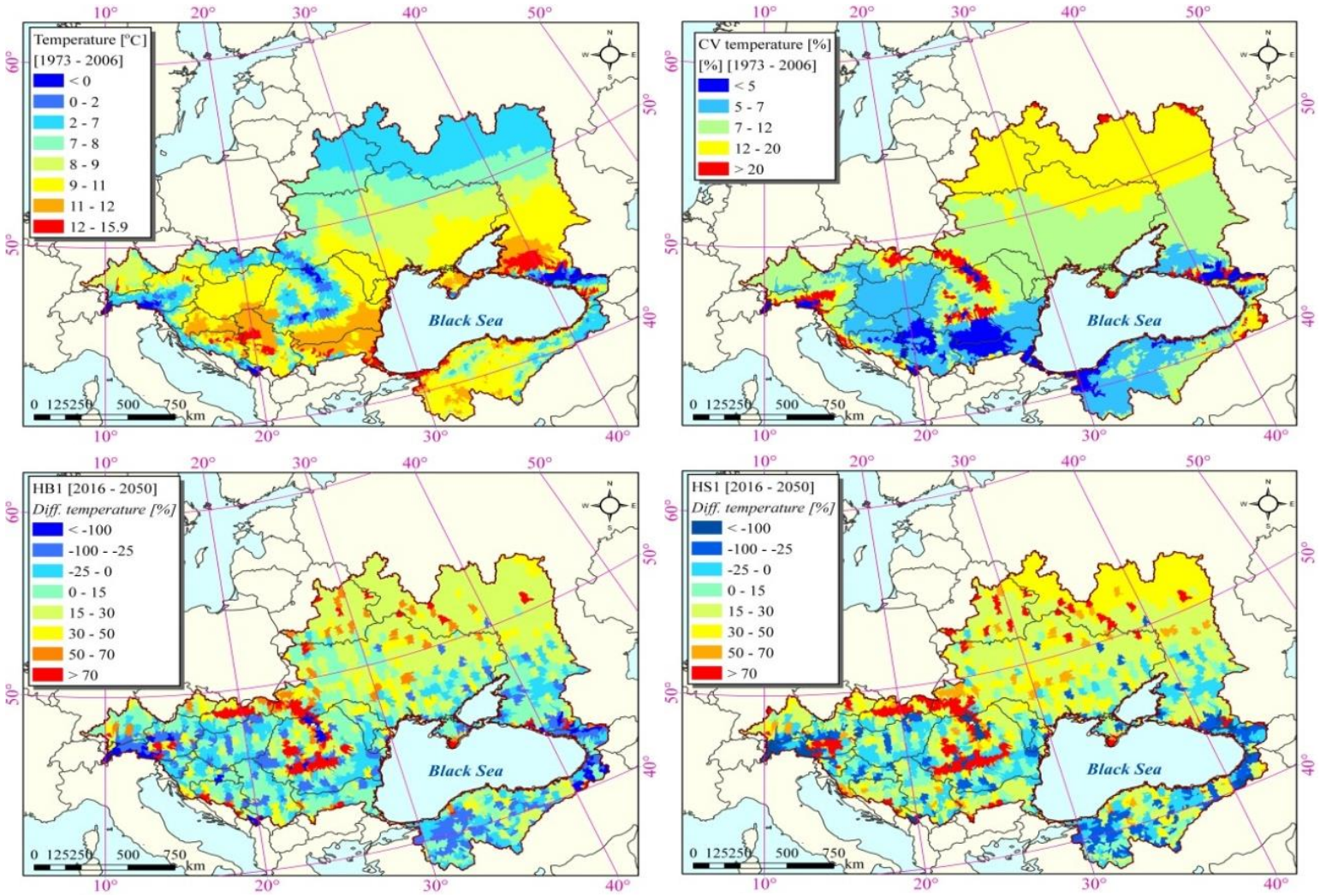
Temporal variation



Future climate scenarios (temperature)

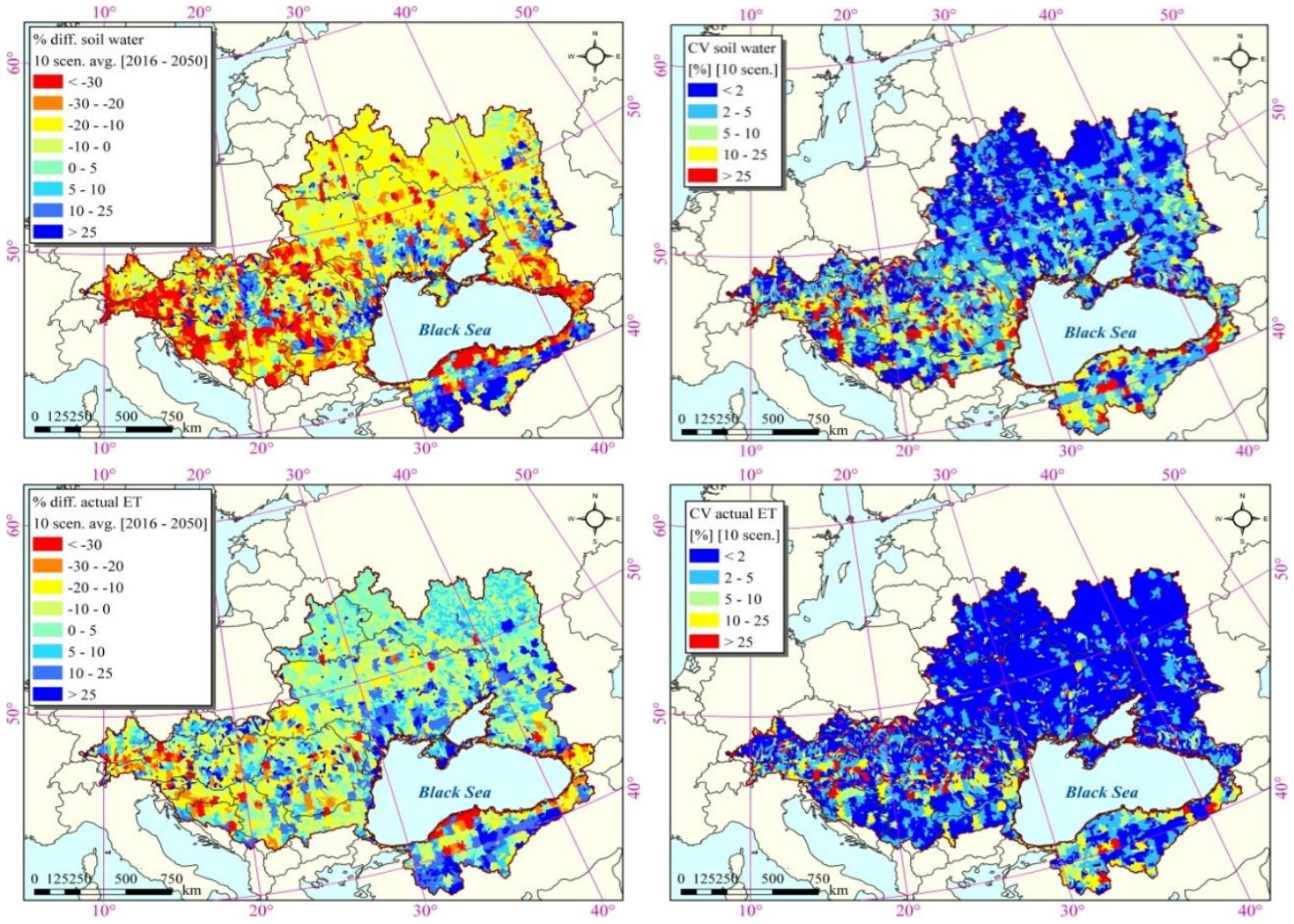
Historic

Temporal variation



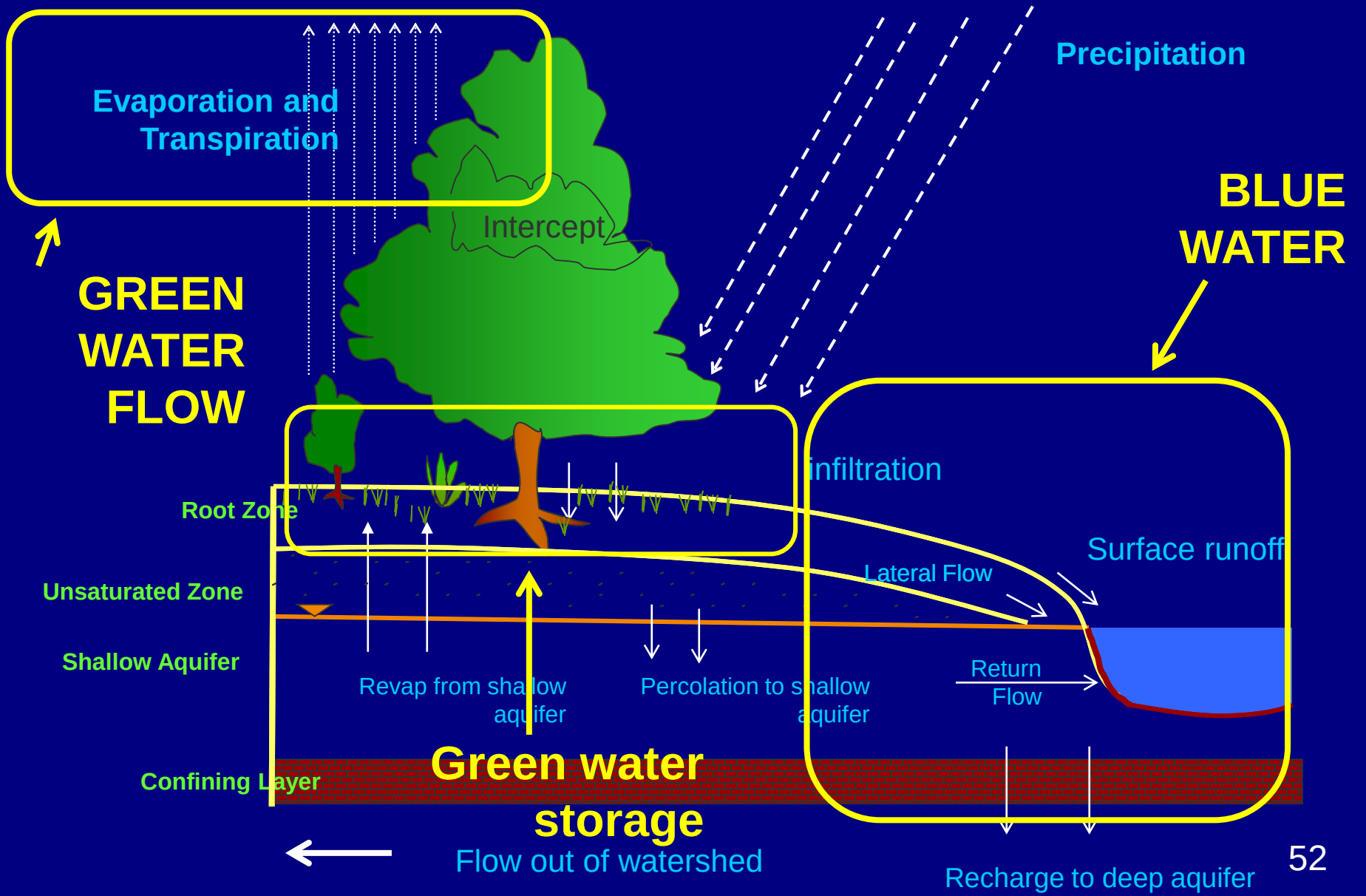
Green water storage and green water flow, deviation from historic,

10 scenarios average



1. SWAT, Land Phase

Conceptual model of Hydrology in SWAT



Build databases (issue 1)

- To build a project:

DEM, Soil, Landuse, River, Climate, Ag. Management

-To calibrate a project:

River discharge, Water quality variables, Crop yield, etc.

Related Articles

Setting up a hydrological model of Alberta:
Data discrimination analyses prior to calibration

Faramarzi, et al., Environmental Modeling and Assessment

Assessing the uncertainties of different input datasets and climate change scenarios

Bahareh Kamali, et al., Hydrological Processes


Viar
Viar
Rio Guadalquivir
Latitude 37.5914 N
Longitude 5.8663 W
Altitude 54 feet
300 yrds