Modelling basin-scale sediment dynamics for the Swiss part of the Rhine catchment

Design Project 2020

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Deltares
Enabling Delta Life

EPFL

Contents

1. Introduction

- Hydrological behavior of a catchment plays a central role in **water resource management** and **water supply**.
- Understanding sediment dynamics is crucial for many applications of inland water management such as **reservoir** and **flood management** or **water quality predictions**.
- **Pollutants** like heavy metals can also be transported by the sediment load within a river

Junction of Rhône and Arve in Geneva, Switzerland.
Source: Jeremy.toma, https://fr.wikipedia.org/wiki/Fichier:Jonction_de_Gen%C3%A8ve.jpg

Oberaarsee, Switzerland

2. Objectives

- *Deltares* is adding **a model for sediment dynamics** *wflow_sediment*, to their already widely used hydrological model *wflow_sbm.*

- **Main goal:** Test the sediment model in a an alpine catchment in Switzerland

2. Objectives - Procedure

CATCHMENT CHOICE AND DATA ACQUISITION

RUNNING THE MODELS *WFLOW_SBM* AND *WFLOW_SEDIMENT*

RESULT ANALYSIS

3. Theoretical background: *wflow_sbm*

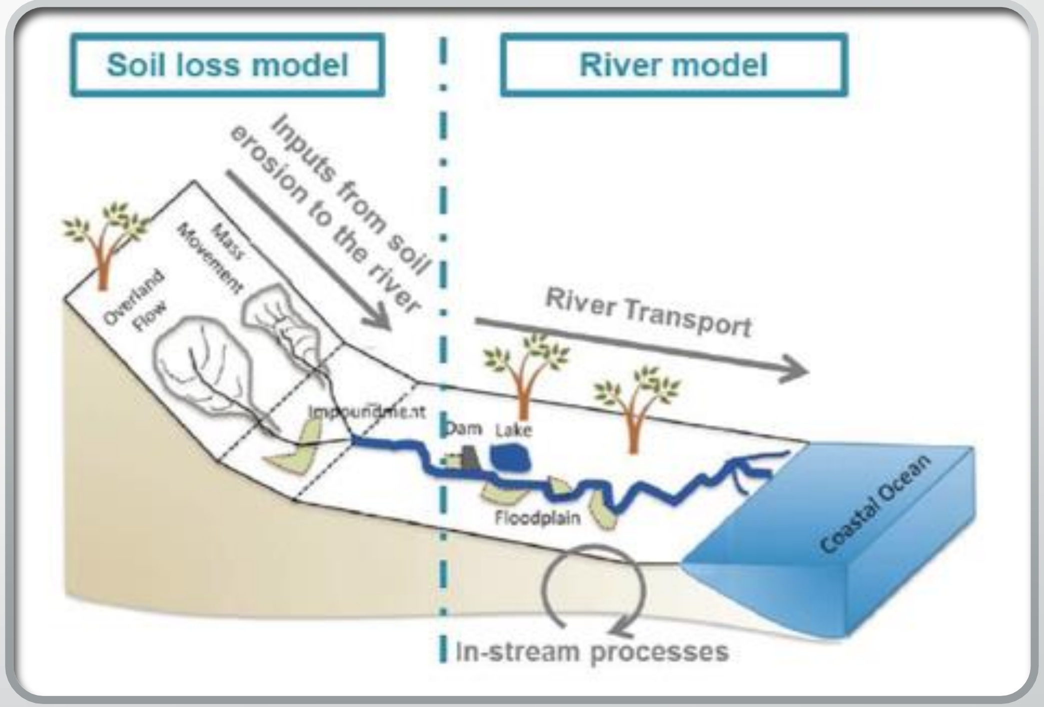
- Fully **distributed** rainfall-runoff model
- Fluxes calculated for each cell
- Uses globally available datasets
- Estimation of the parameters

Lumped | *Semi-distributed* | *Distributed*

Figure 2 : types of hydrological models

3. Theoretical background: *wflow_sediment*

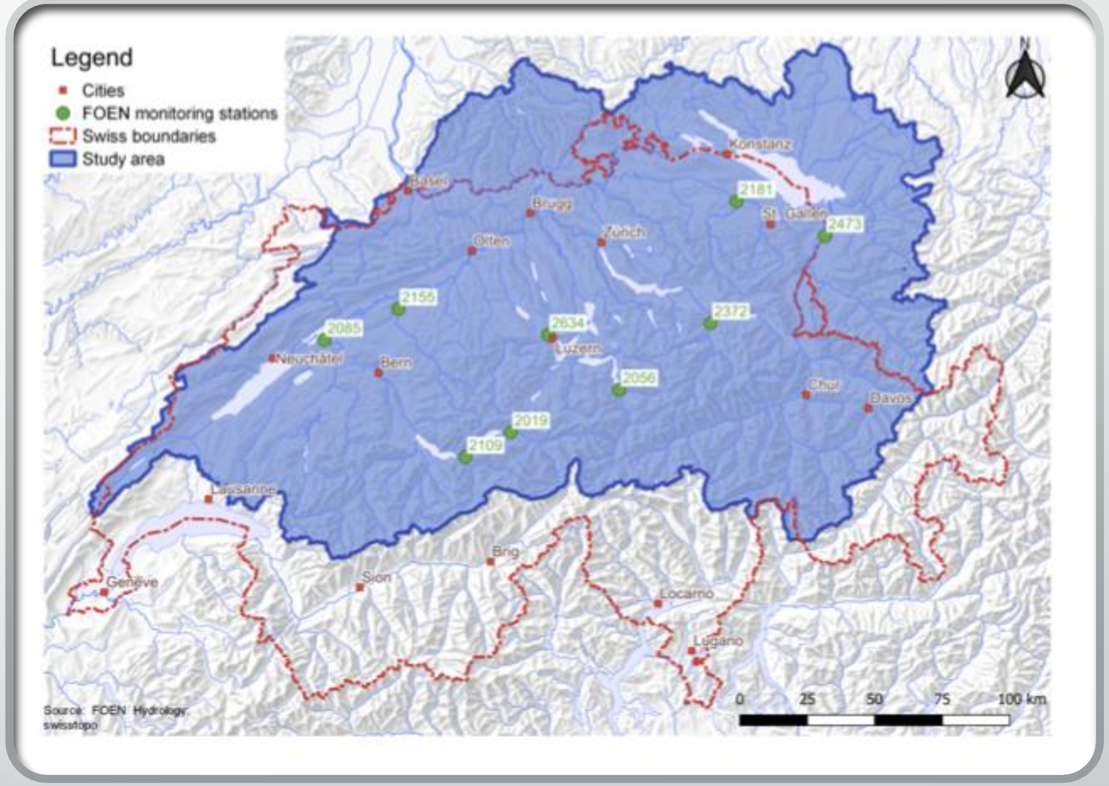
- Based on the *wflow_sbm* model.
- May use more **physics-based** or more **empirical** equations.
- Clearly distinguishes land and river cells.
- Contains a **soil loss** part and a **river transport** part.
- Focus on Soil loss part



Overview of sediment pathways

4. Methods: catchment choice

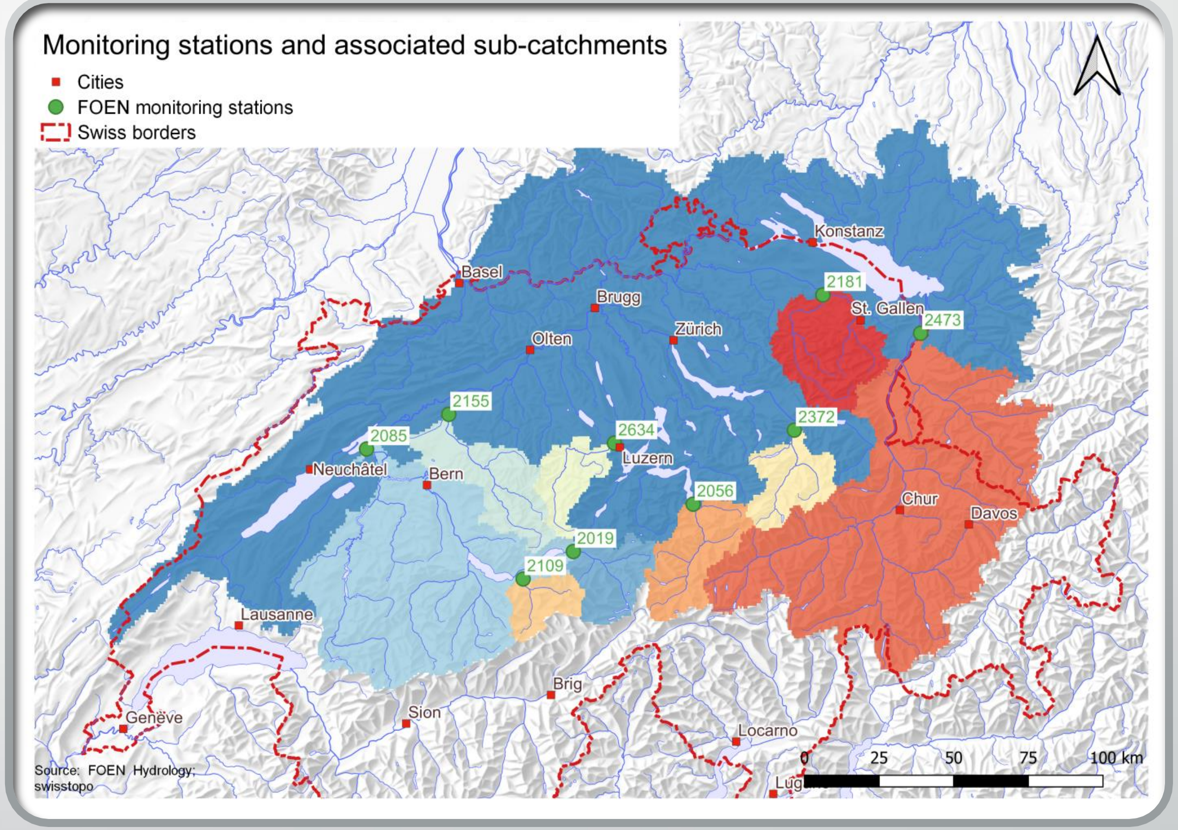
- **9** monitoring and measuring stations in Switzerland.
- The whole Rhine catchment can be studied over a **15-years long period (2001 - 2015)**.



The Swiss Rhine catchment and FOEN monitoring stations

4.Methods: Hydrology

- Efficiency without calibration :
  - Nash-Sutcliffe (NSE) and Kling-Gupta Efficiency (KGE)
  - Scatter plot of measured vs. modelled water flow



Monitoring stations and their associated sub-catchments

4. Methods: Soil Loss

- Total of 4 runs
- Test of 2 methods for soil erodibility factor K
  - EPIC and Renard
- Test of 2 methods for rainfall erosion D_R
  - ANSWERS and EUROSEM

ANSWERS

$$D_R = 0.108 * C_{USLE} * K_{USLE} * A_i * R_i^2$$

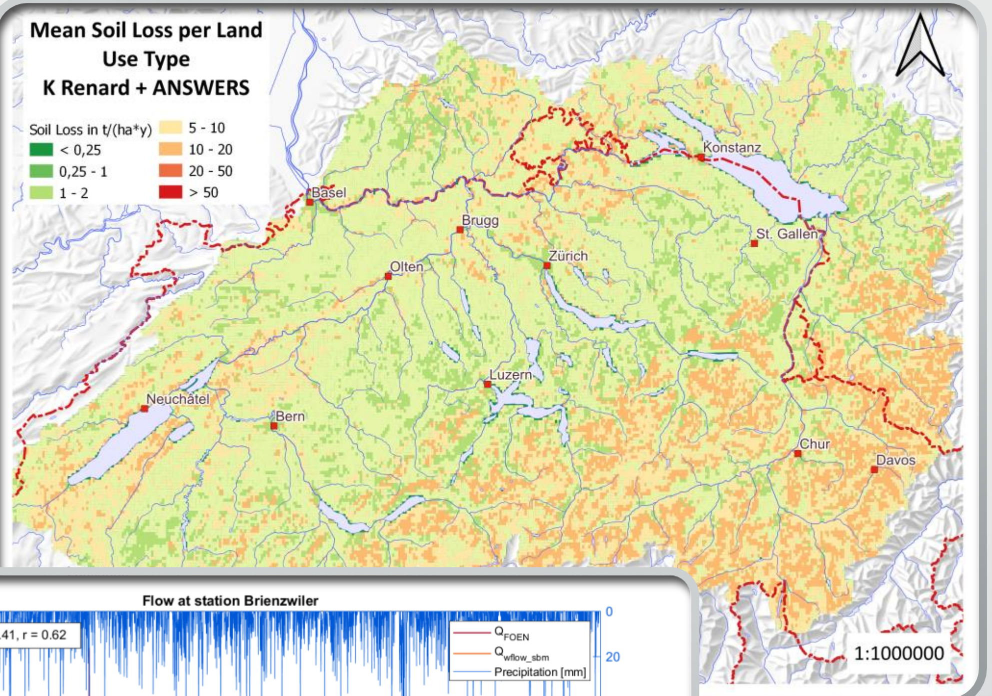
C_{USLE} :	parameter
K_{USLE} :	parameter
A_i :	area of cell
R_i :	rainfall intensity

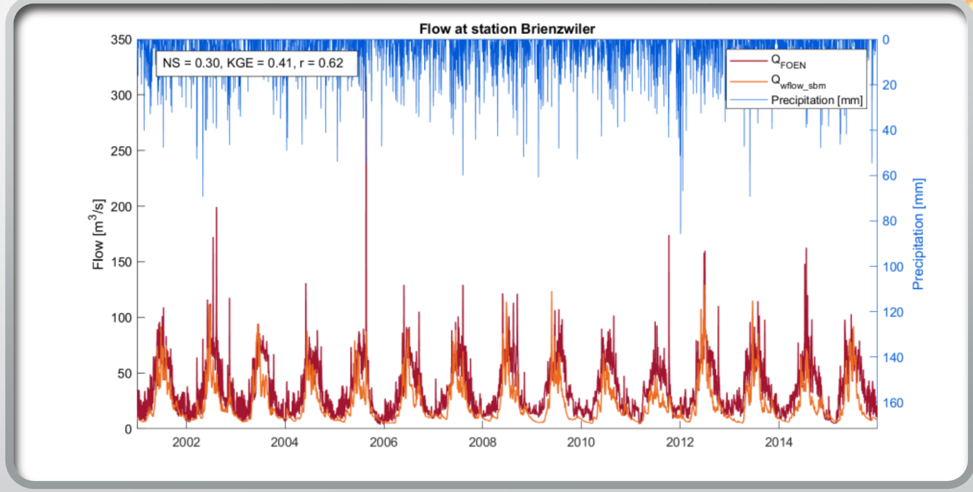
EUROSEM

$$D_R = k * KE * e^{-\varphi * h}$$

k :	index of detachability
KE :	total rainfall kinetic energy
φ :	exponant
h :	runoff depth

5. Results


Mean Soil Loss per Land Use Type
K Renard + ANSWERS
Soil Loss in t/(ha*y)
< 0,25
0,25 - 1
1 - 2
5 - 10
10 - 20
20 - 50
> 50
Basel
Konstanz
Brugg
St. Gallen
Zürich
Olten
Luzern
Neuchatel
Bern
Chur
Davos
1:1000000


Flow at station Brienzwiler
NS = 0.30, KGE = 0.41, r = 0.62
Q_FOEN
Q_wflow_sbm
Precipitation [mm]
Flow [m3/s]
Precipitation [mm]

5. Results : Hydrology

- **Good** overall performance
- Exception is station 2085
- Clear underestimation of flow rates for peak events.
- Snow-melt modelling can be improved.

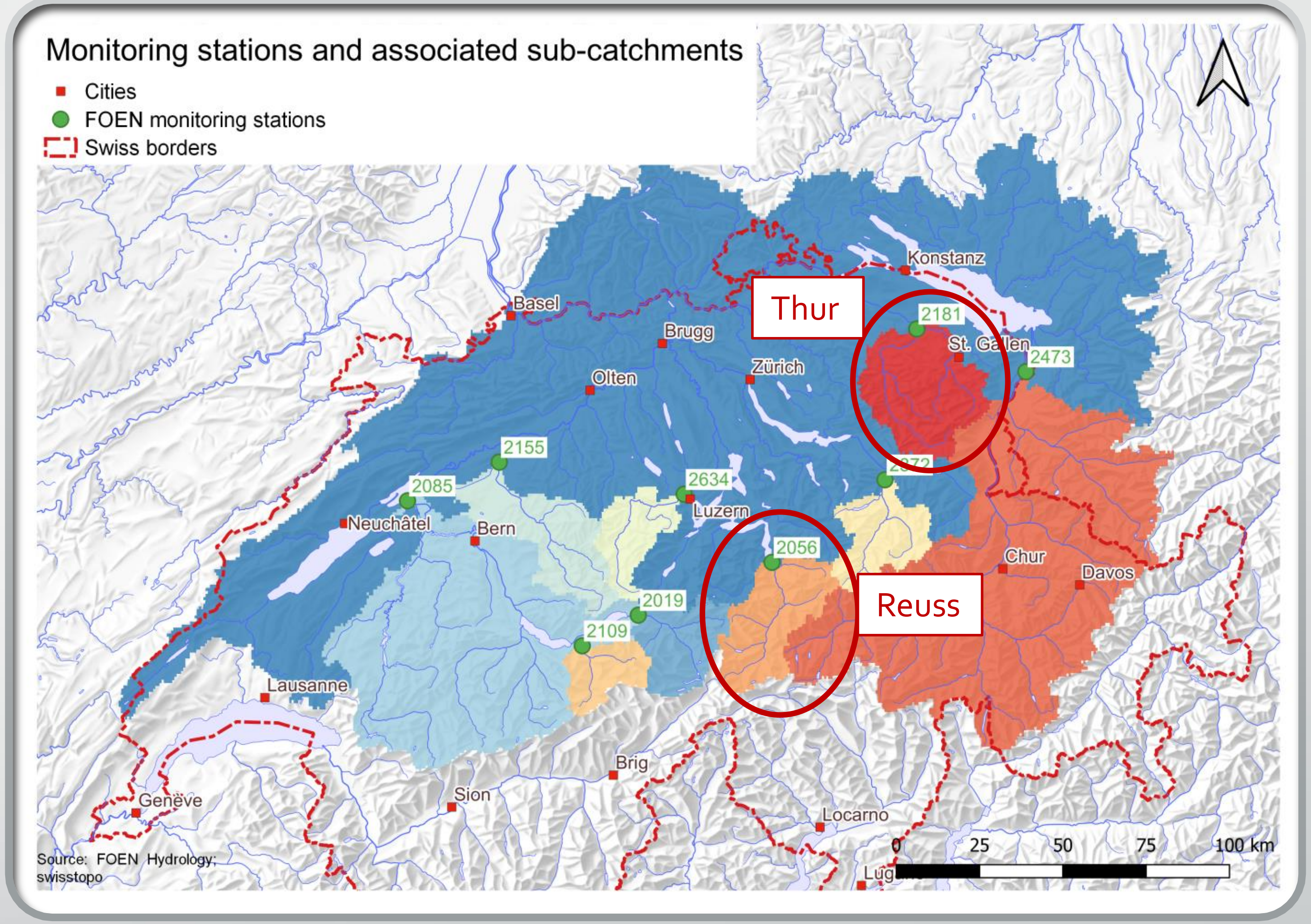
Station Number	NSE	KGE	r
2019	0.297	0.414	0.619
2056	0.601	0.719	0.811
2085	-0.126	0.094	0.541
2109	0.574	0.418	0.634
2155	0.367	0.670	0.634
2181	0.217	-0.005	0.382
2372	0.139	0.457	0.626
2473	0.419	0.616	0.736
2634	0.243	0.043	0.402

Table 1: Model efficiency quantification: NSE and KGE coefficient and parameter r for the 15-year fit

5. Results : Hydrology

- **Highlight** detailed results for two stations

	Reuss	Thur
Area [km²]	833	1085
Mean elevation [m.a.s.l]	2007	910



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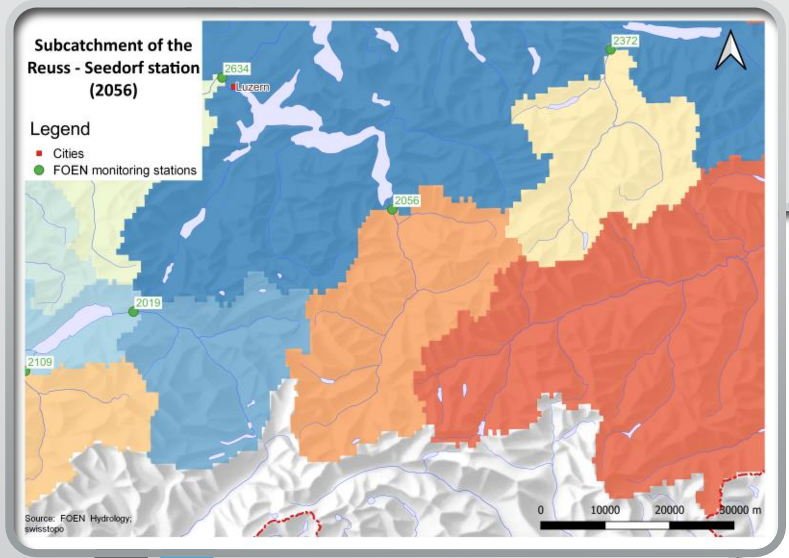
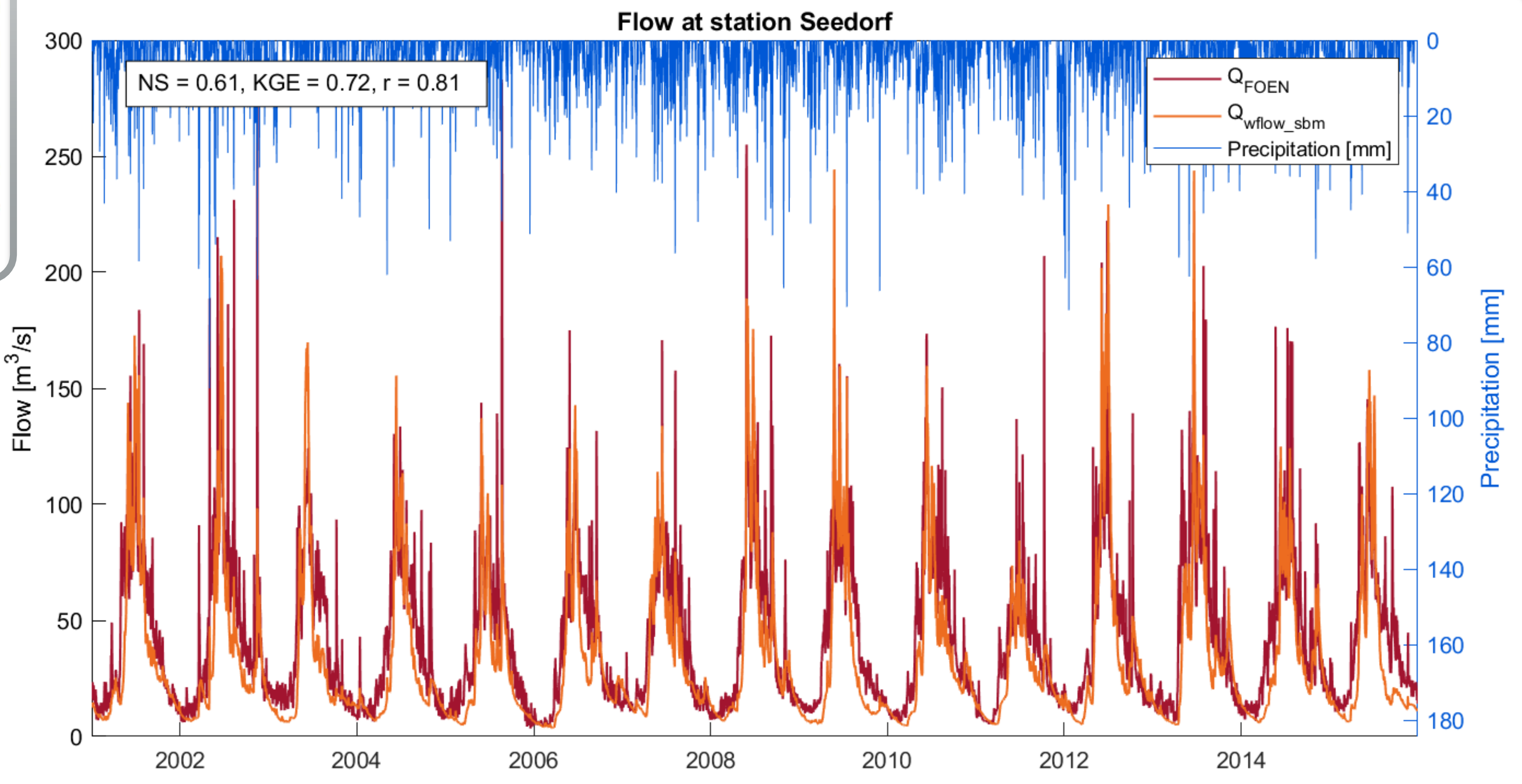
5. Results : Hydrology

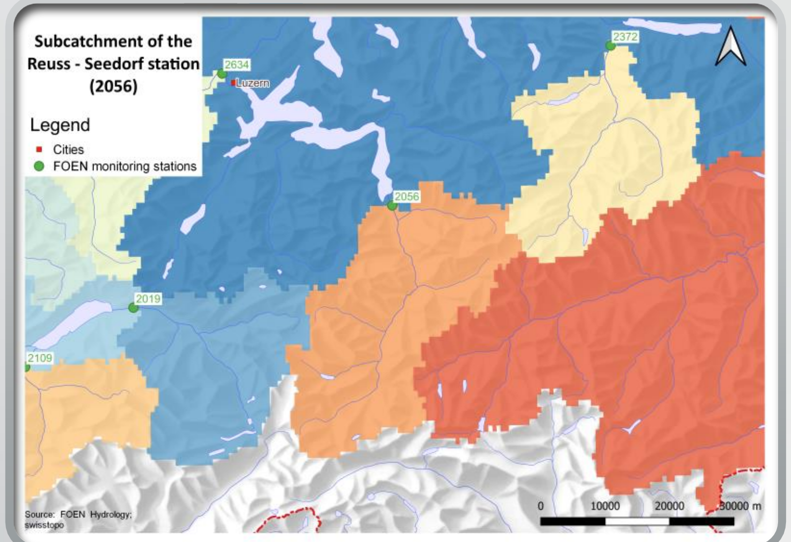


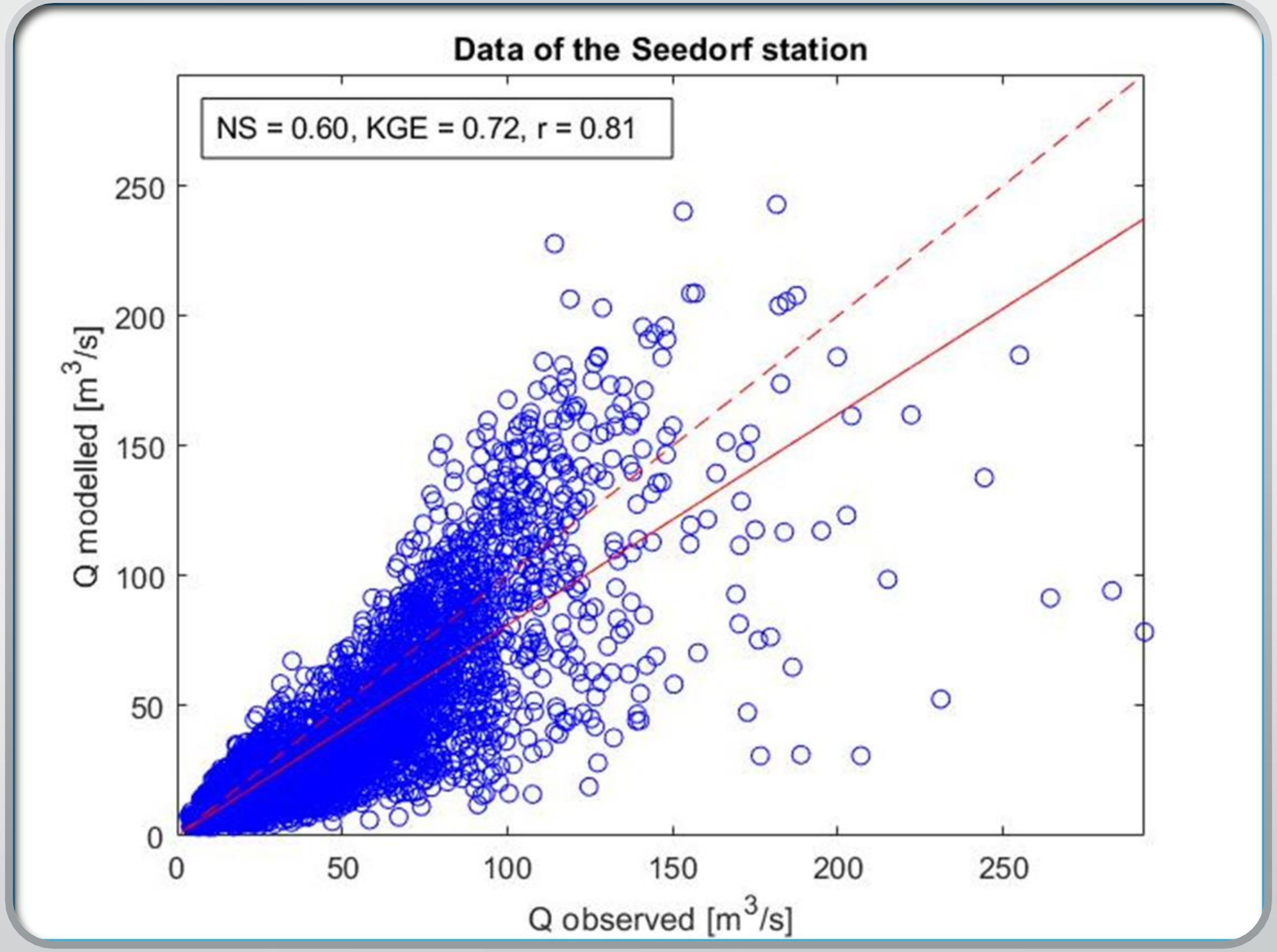


Modelled and measured flow at the Seedorf Station (2056). The precipitation over the Reuss sub-catchment can be appreciated on the right vertical axis.

EPFL

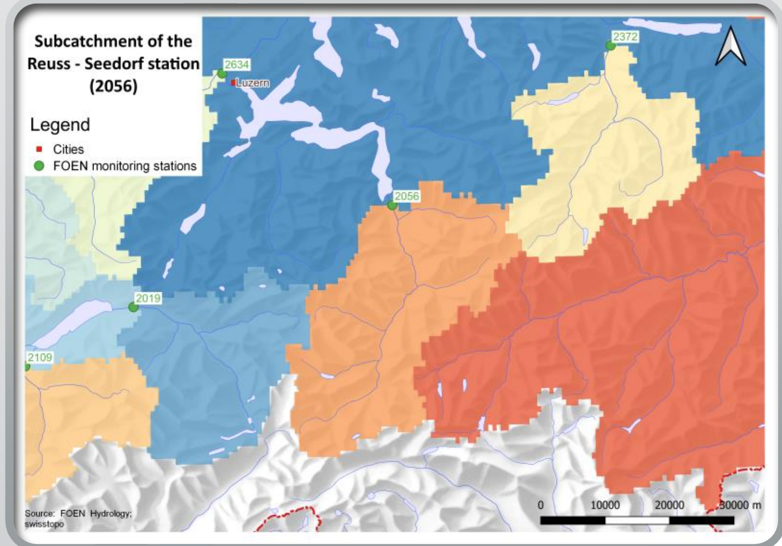
5. Results : Hydrology

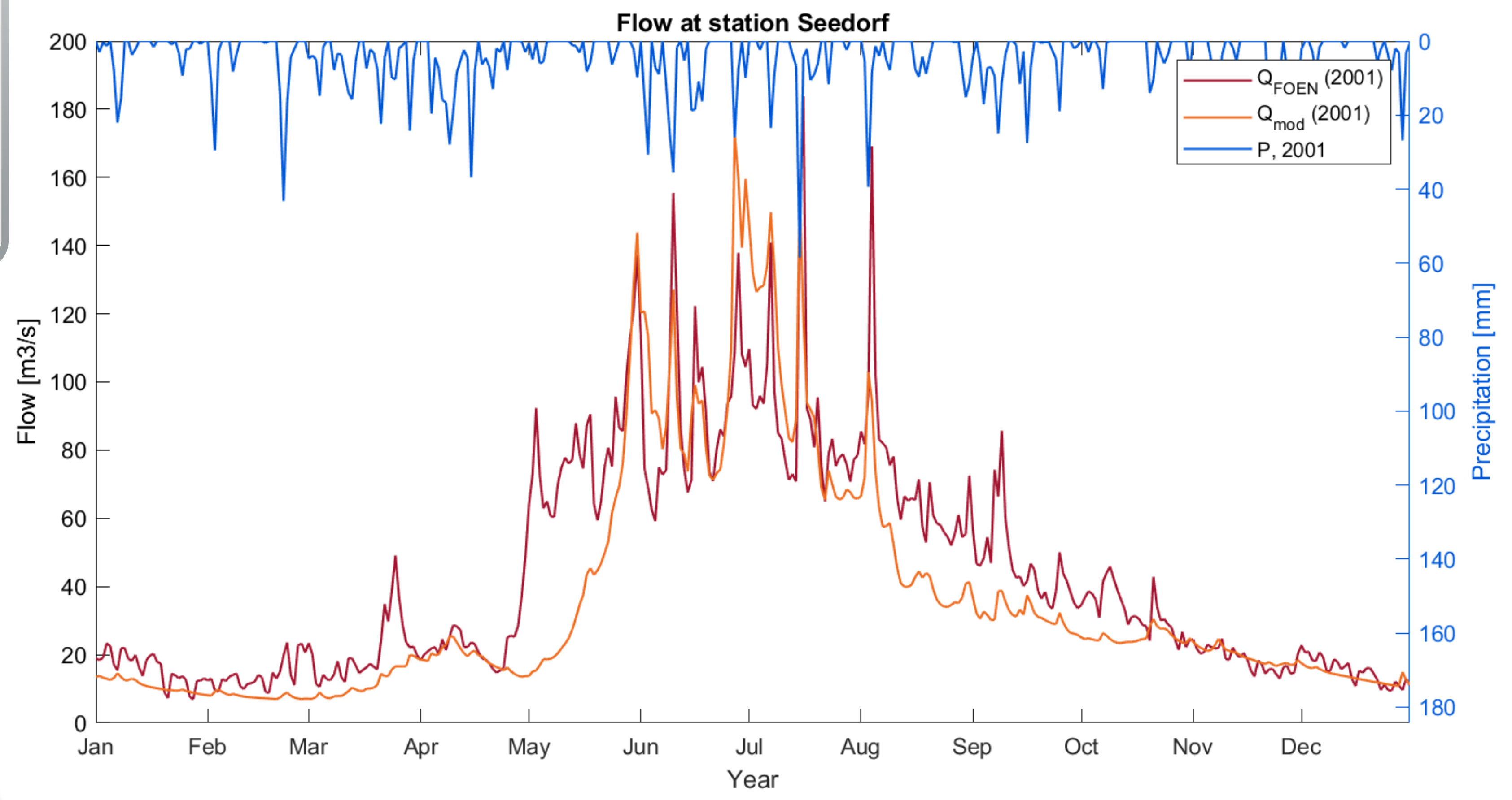




Scatter plot at the Seedorf Station, r = 0.81. The dashed-line has a slope of 1

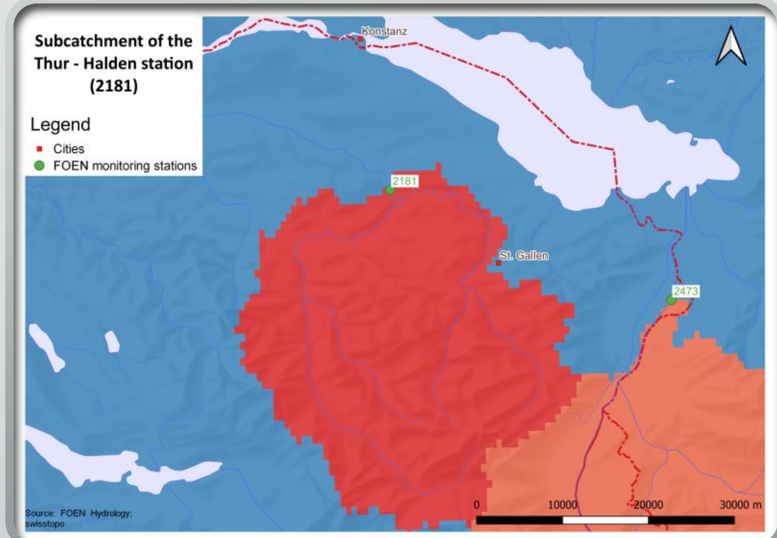
5. Results : Hydrology

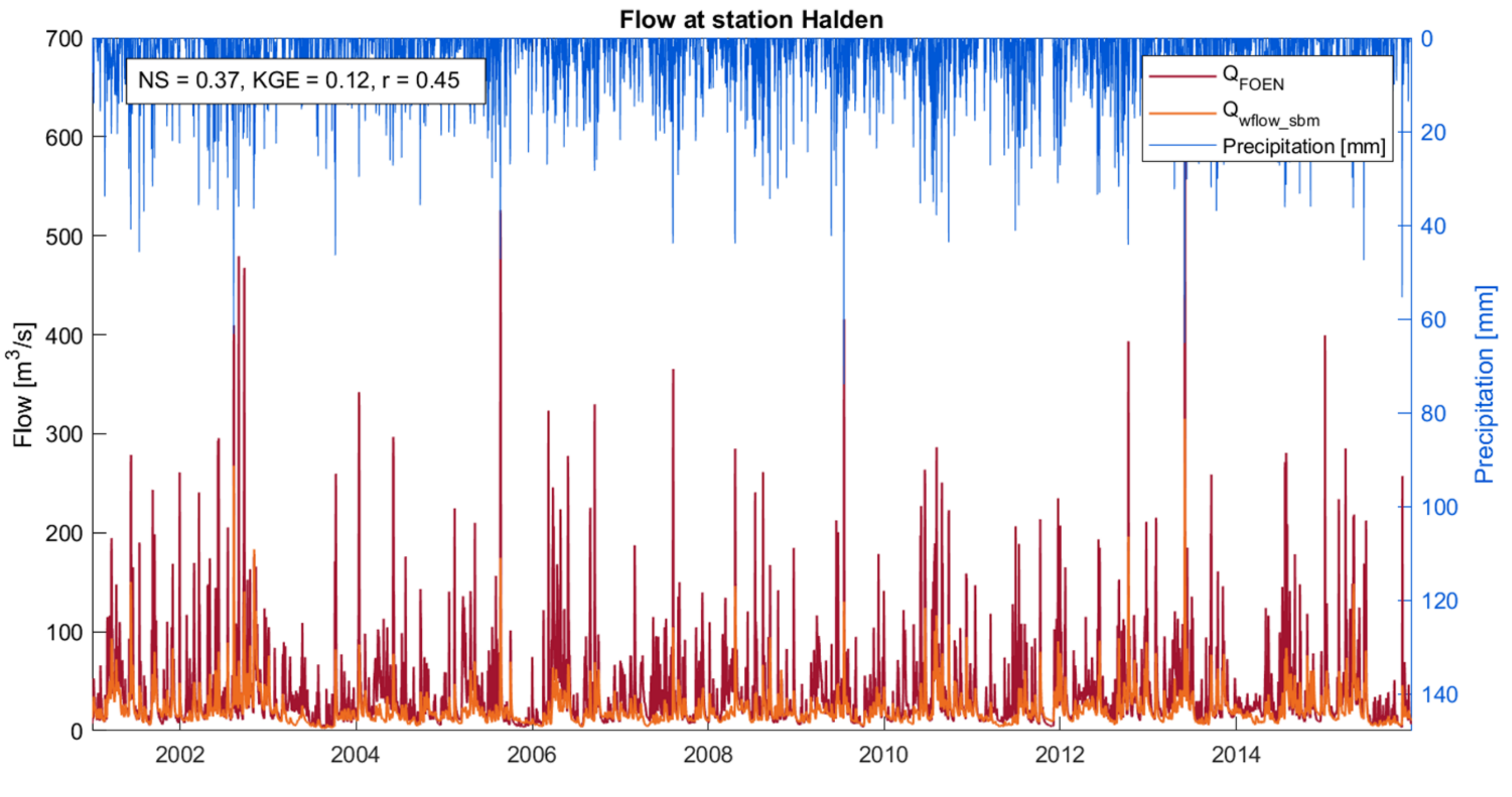




Modelled and measured flow at the Reuss Seedorf (2056) station, detailed for the year 2002. The precipitation over the Reuss sub-catchment can be appreciated on the right vertical axis.

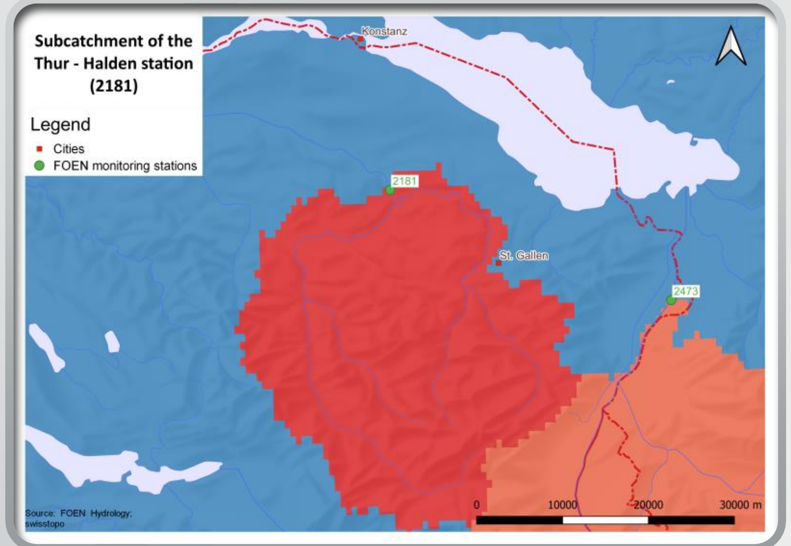
5. Results : Hydrology

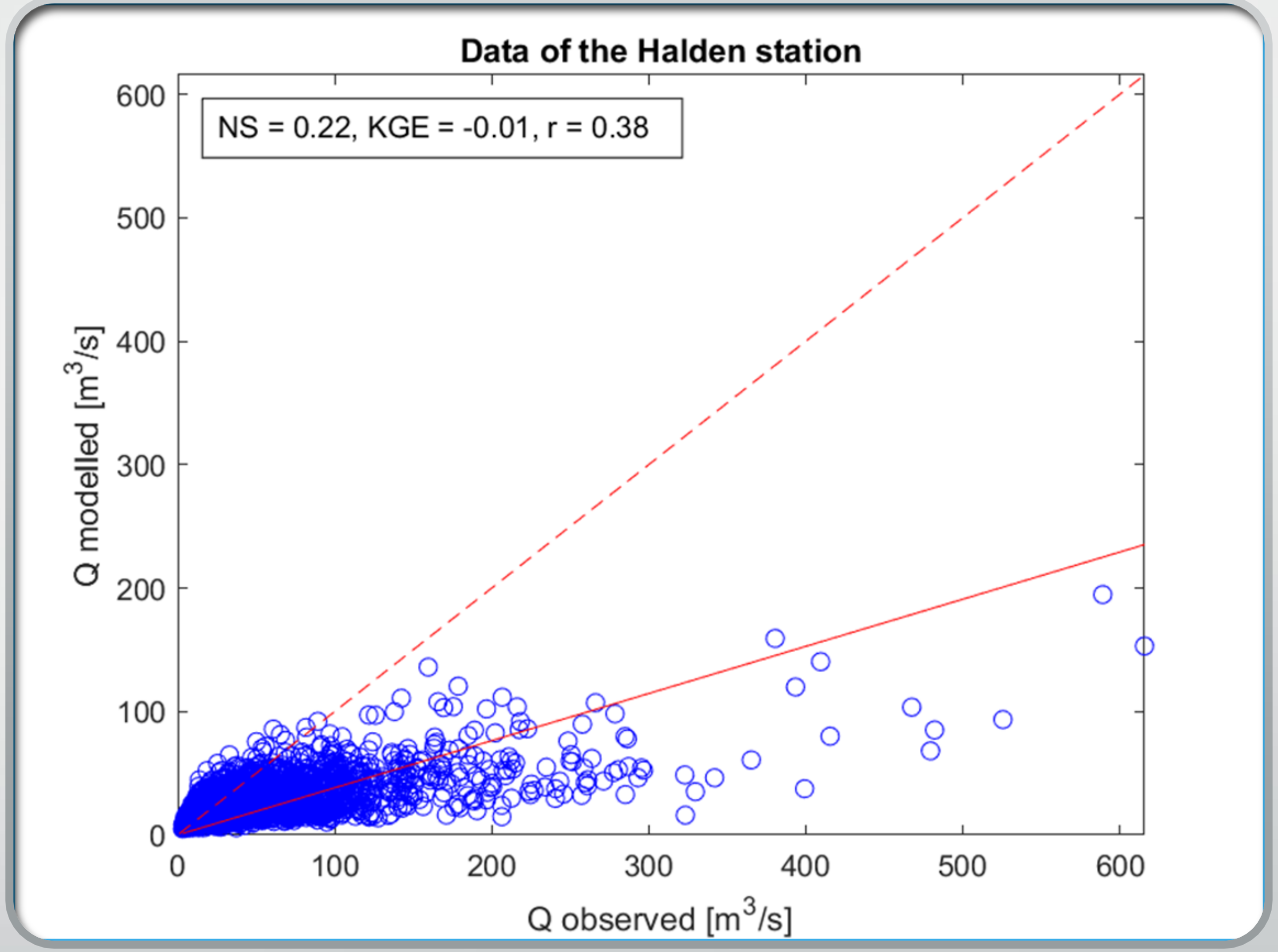




Modelled and measured flow at the Thur, Halden (2181). The precipitation over the Thur subcatchment can be appreciated on the right vertical axis.

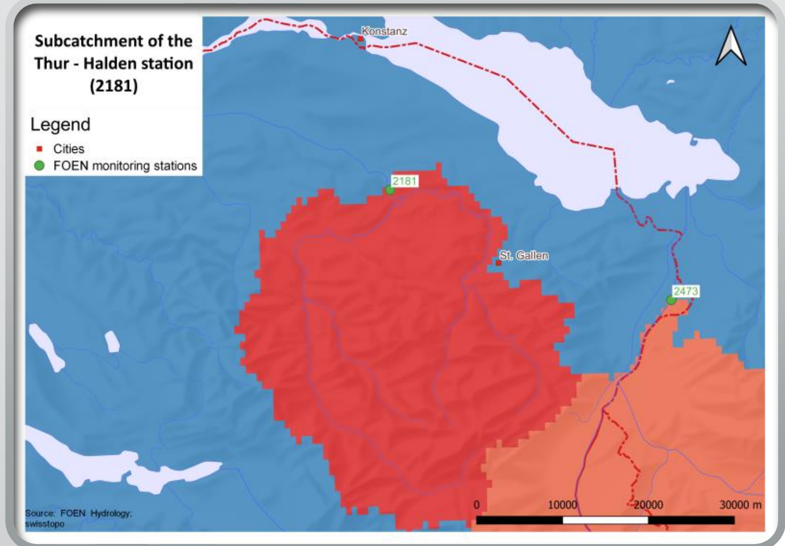
5. Results : Hydrology

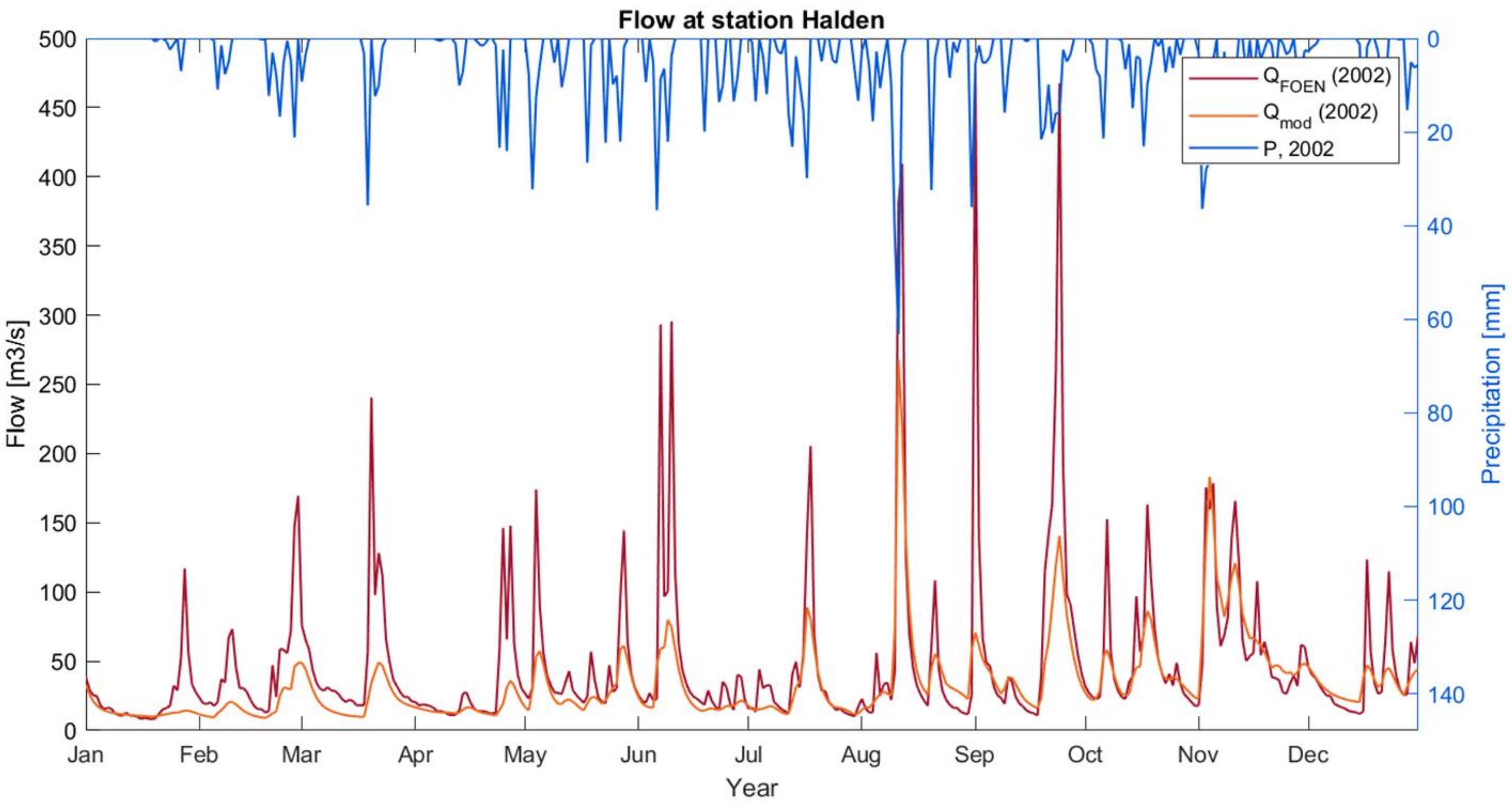




Scatter plot at Thur Halden Station, r = 0.38. The dashed-line has a slope of 1

5. Results : Hydrology





Modelled and measured flow at the Thur Halden (2181), detailed for the year 2002. The precipitation over the Thur sub-catchment can be appreciated on the right vertical axis.

5.Results: Soil loss

- **High heterogeneity** of results in the Alps
- Different areas of high erosion also on the plateau and close to the Jura.
- Influence of overland flow, slope and land cover

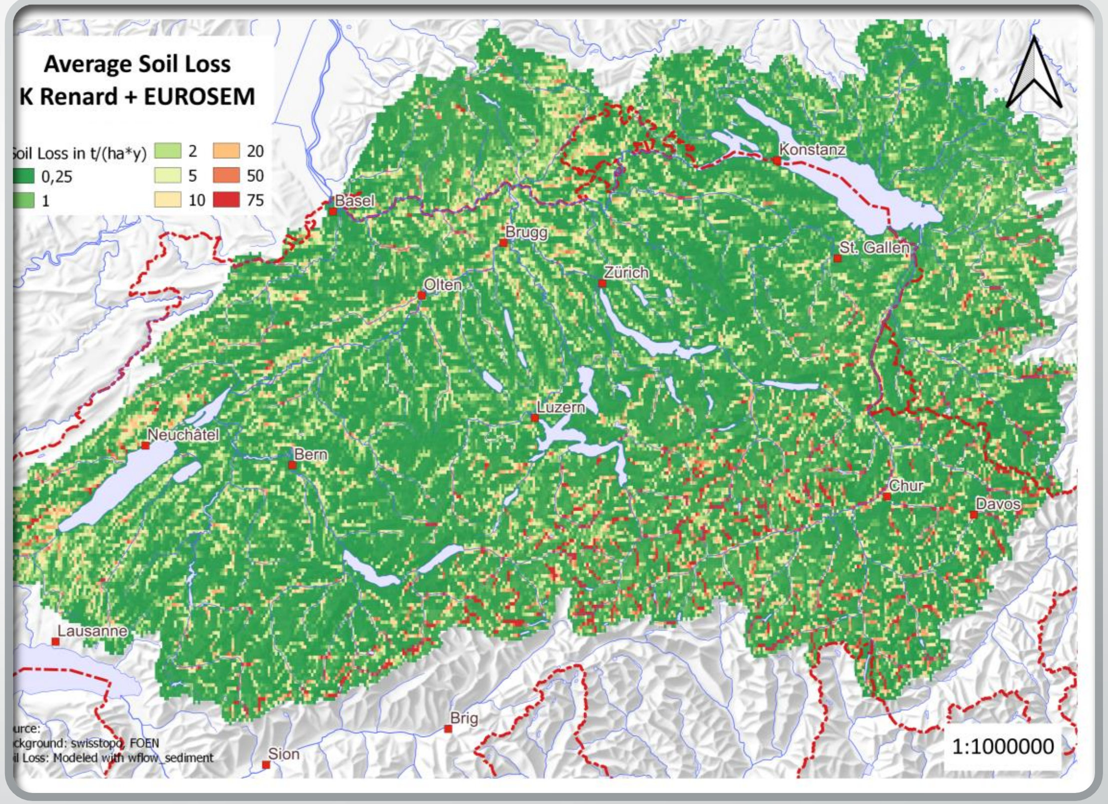
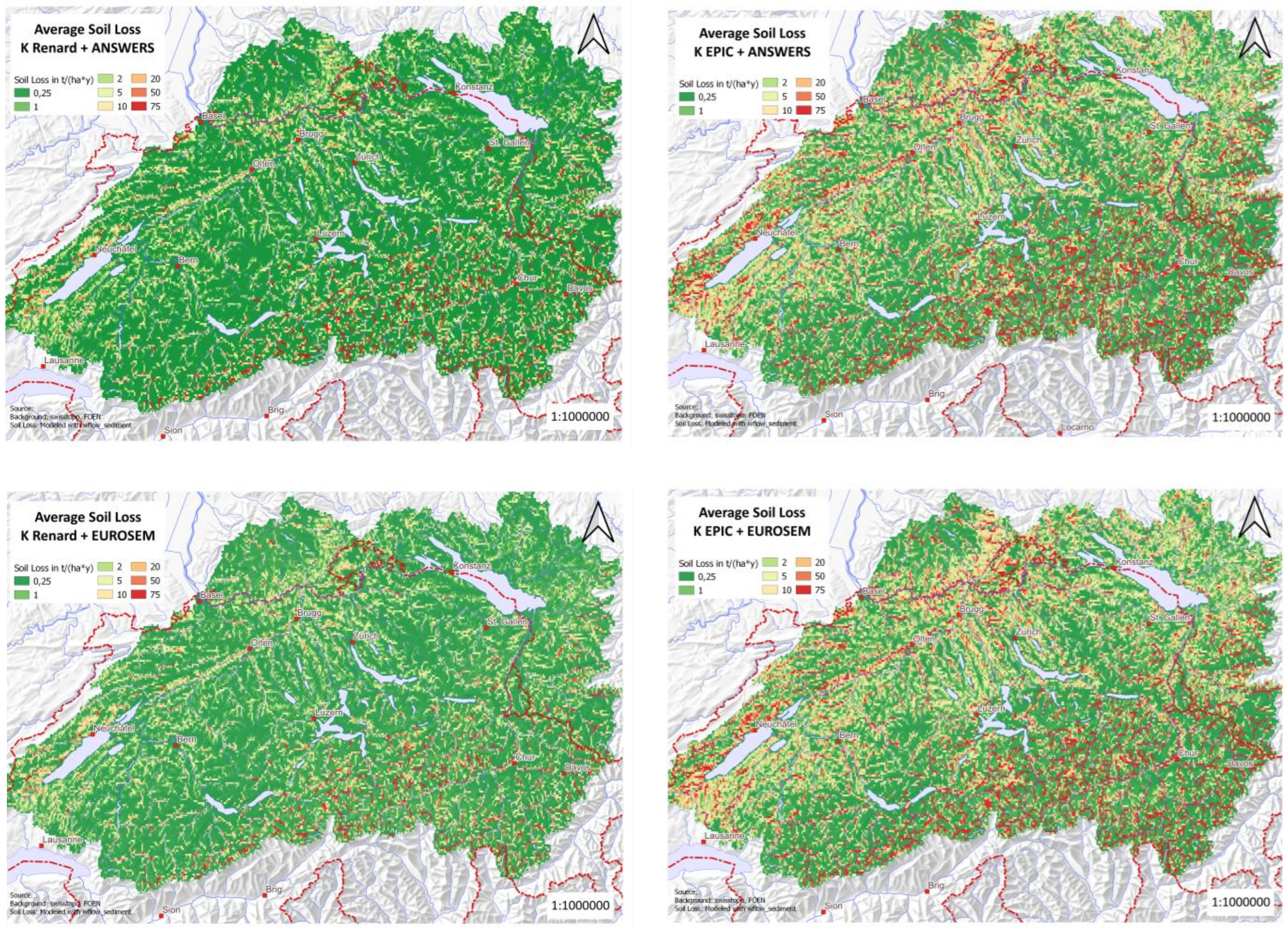


Figure 10: Map of modelled average Soil loss using the Renard method for soil erodibility K and the EUROSEM equations for rainfall erosion.

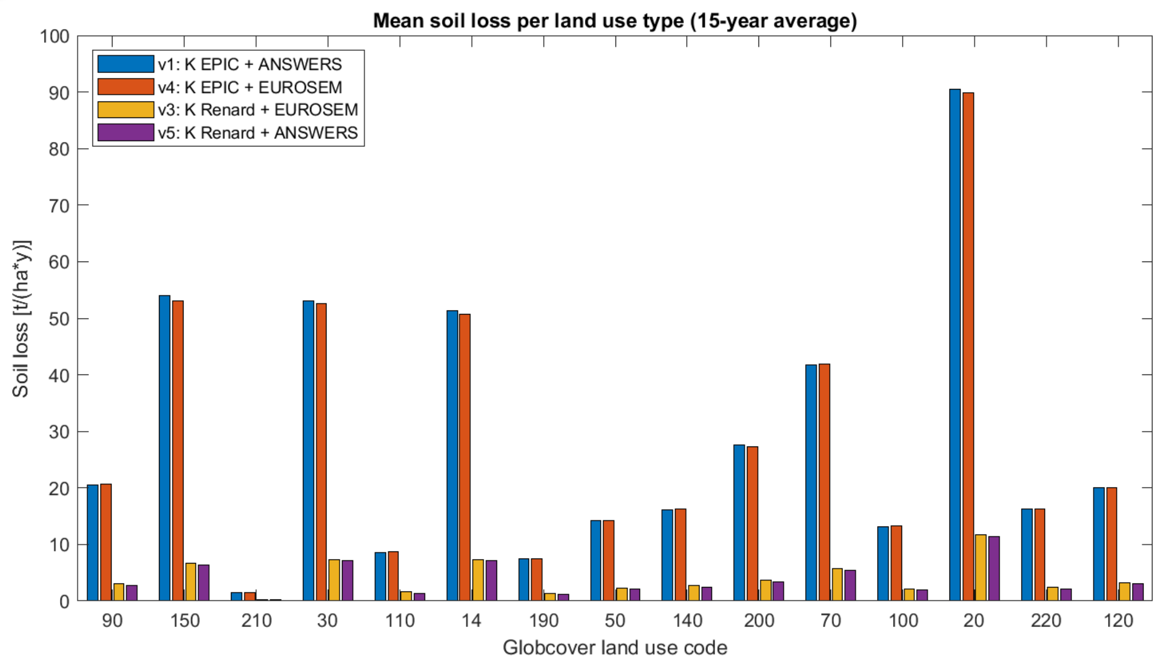
5. Results: Soil loss

- Big differences between Renard and EPIC
    - Results an roughly an order of magnitude higher
- Only small differences between ANSWERS and EUROSEM



5. Results: Soil loss

- Large differences between types of land cover, mainly **depending on density of vegetation**



Land use type (Code)	Land use type (Name)
50	Closed (>40%) broadleaved deciduous forest (>5m)
20	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)
120	Mosaic grassland (50-70%) / forest or shrubland (20-50%)
30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)
140	Closed to open (>15%) herbaceous vegetation (grassland savannas or lichens/mosses)
70	Closed (>40%) needleleaved evergreen forest (>5m)
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (¿5m)
14	Rainfed croplands
210	Water bodies
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)
150	Sparse (>15%) vegetation (woody vegetation, shrubs, grassland)
200	Bare areas
190	Artificial surfaces and associated areas (Urban areas >50%)
220	Permanent snow and ice
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)

5. Results :Soil Loss

- Comparison with Panagos et al. who used a *RUSLE2015* model.
  - Soil loss rates in between Austria and France using the Renard method
- Comparison of soil loss per land use type:
  - Plausible results for Forest and Grassland
  - Maybe an overestimation for cropland
- Comparison with FOEN study in Alpine valleys:
  - Similar order of magnitude although high range of local results

Country	Mean soil loss [t/(ha*y)]
Austria	7.19
France	2.25
Germany	1.25
Italy	8.46
wflow_sediment	
v1: K EPIC + ANSWERS	31.81
v2: K EPIC + EUROSEM	32.71
v3: K Renard + EUROSEM	4.65
v5: K Renard + ANSWERS	4.44

Source	Forest	Cropland	Grassland
Cerdan (Europe)	0.2	3.6	0.4
Maetens (Europe)	0.7	6.5	0.7
RUSLE2015 (Rhine, year 2010)	2.61	2.16	2.53
PESERA (Rhine, year 2003)	0.33	1.62	0.73
wflow_sediment (Rhine years 2010 to 2014)	0.28	1.50	0.45
wflow_sediment (Swiss part of the Rhine catchment, years 2001 to 2015)	2.81	10.44	4.40

6. Conclusion

- The hydrological model has a good and stable overall performance, despite an the soil loss underestimation of flow peaks.
- Estimation works best with the *Renard* method. There are no significant difference between EUROSEM and ANSWERS.
- The results for the modelling of the river transport can be found in the report of this project
- This project may lay the basis for more testing and analysis on this interesting catchment (influence of slope, canopy cover,… direct comparison with other soil erosion models)

Special thanks to Hélène Boisgontier and Paolo Benettin for your support and your advice !

Thank you for your attention !

Image by David Burg