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Institute for Environment and Sustainability

KATHOLIEKE UNIVERSITEIT LEUVEN

SWAT MODELLING AT PAN EUROPEAN SCALE: THE DANUBE BASIN PILOT STUDY

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SWAT MODELLING AT PAN EUROPEAN SCALE: THE DANUBE BASIN PILOT STUDY

- Introduction
- The Danube
- Model
  - Available databases
  - Model set up
- Modelling protocol
  - Hydrological regionalization
  - Calibration
- Results
- Conclusions and comments

INTRODUCTION - Framework

- Implementation of European environmental legislation
- Statistical approach: GREEN (Geospatial Regression Equation for European Nutrient Losses)
  - Total loads of nutrients into European seas in ton/year
- Hydrological model selected: SWAT
  - Widely used
  - Modular structure
  - Public domain
  - ArcSWAT interface

INTRODUCTION – Facing a large scale modelling

- Modelling protocol to overcome
  - Hydrological regionalization from gauged to ungauged catchments
  - Over-parameterization and identifiability problems: the fact that there are many different parameter sets that describe equally well the observed data set.
    - ➢ Improving calibration transparency

DANUBE

- 803,000 km^2
- 14 countries:

  Austria
  Bosnia & Herzegovina
  Bulgaria,
  Croatia
  Czech Republic
  Germany
  Hungary
  Moldova
  Montenegro
  Romania
  Serbia
  Slovakia
  Slovenia
  Ukraine.

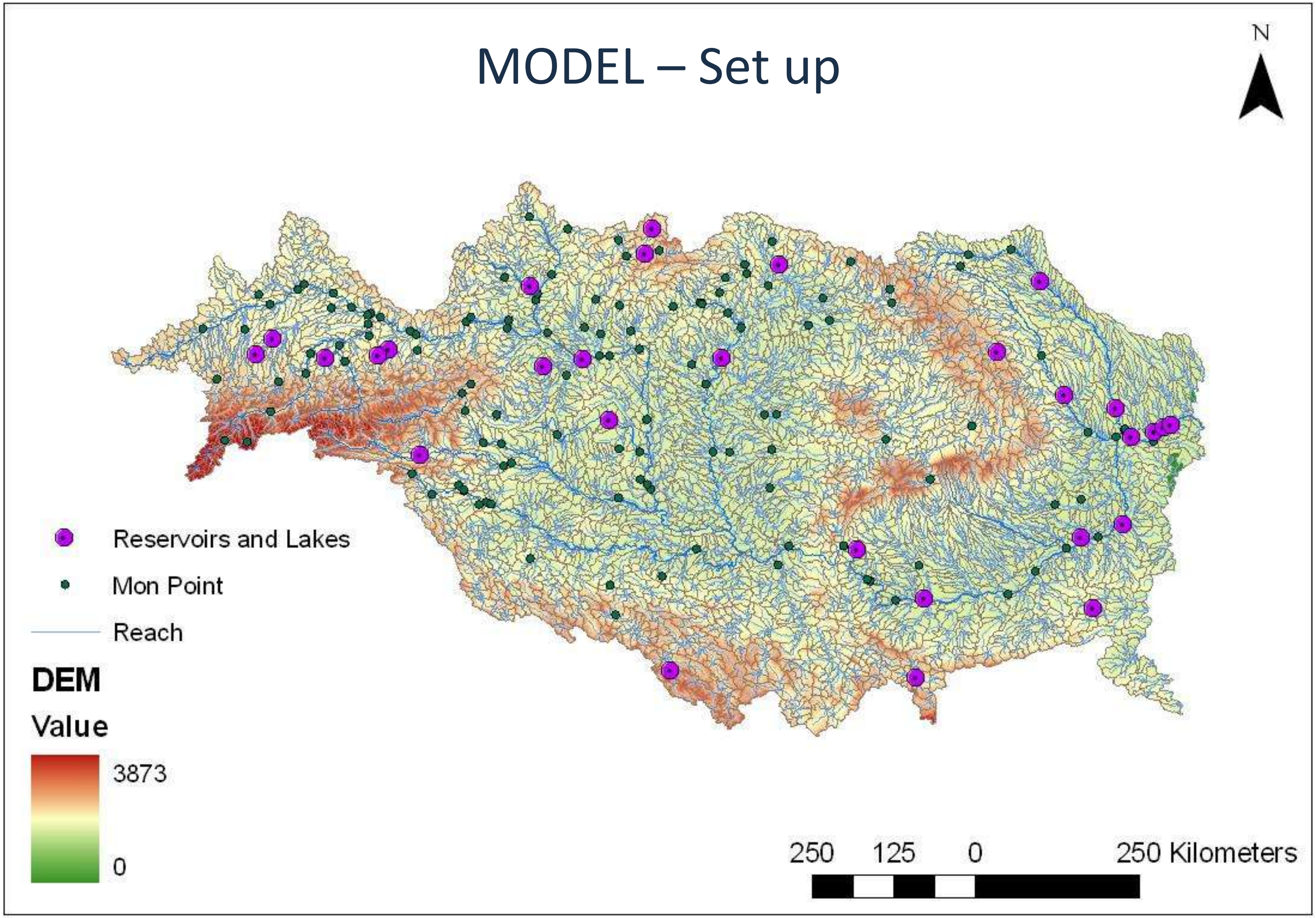
MODEL – Model input

- DEM: 100 × 100 m. Obtained from the Shuttle Radar Topography Mission (SRTM)
- LAND USE: 1 × 1 km. – year 2000. Combined data from CAPRI, SAGE, HYDE 3 and GLC2000 databases
- SOIL: 1 km resolution. HWSD Harmonized World Soil Database – FAO
- WATERSHED AND STREAM DELINEATION: Based on CCM2 Catchment database for continental Europe
- RESERVOIRS AND LAKES: GLWD Global Lakes and Wetland and CCM2 databases. Lakes and reservoirs of area larger than 20 km^2.
- CLIMATE DATABASE: MARS: 25 × 25 km interpolation based on the European Meteorological Monitoring Infrastructure.
- MONITORING POINTS: GRDC (Global Runoff Data Centre) and ICPDR (Danube River Protection Convention).

MODEL – Set up

- Area = 833908 km^2
- 4663 subbasins – dominant HRU, average size = 179 km^2
- MARS climate database 25 km
  - 1363 Precipitation and Temperature points
  - 300 Solar Radiation, Wind speed and Relative Humidity points
- 29 Lakes and Reservoirs
- Elevation bands in steep subbasins
- 129 Monitoring points with available data

MODEL – Set up


N
Reservoirs and Lakes
Mon Point
Reach
DEM
Value
3873
0
250 125 0 250 Kilometers

MODELLING PROTOCOL

HYDROLOGICAL REGIONALIZATION

- Similarity approach: Finds for each ungauged catchment a donor catchment that is most similar in terms of catchment attributes, and transposes the complete parameter set to the ungauged catchment.
- Regions with similar hydrological response were determined by catchment and flow characteristics using Cluster analysis.
- The selection of catchment characteristics relevant for clustering procedure was determined by employing Principal Components Analysis (PCA).
- PCA statistical tool that reduces dimensionality of a data set while retaining maximum information.
- Hierarchical cluster analysis: Ward's method.
- Number of clusters: corrected Rand index and the Meila's variation index

MODELLING PROTOCOL

TRANSPARENT CALIBRATION

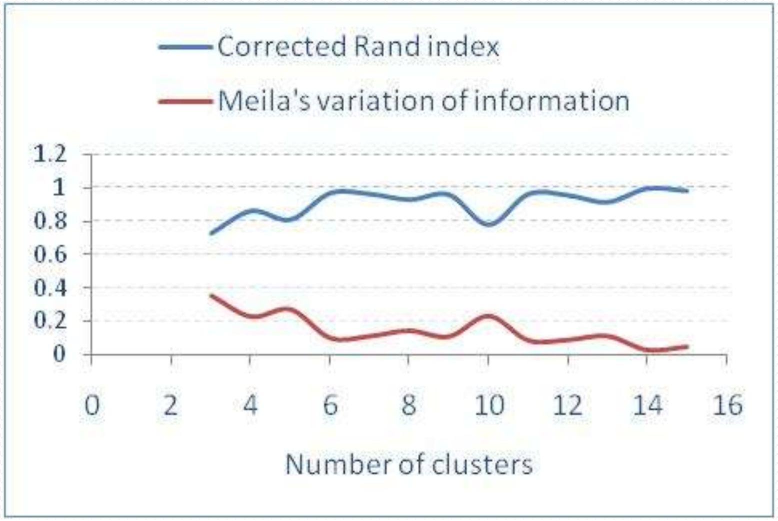
- Sensitivity analysis: LH-OAT method (Van Griensven, 2006).
- Simultaneous SA at subbasin level:Assessment of sensitive parameters using water yield as model output
- Multi-objective calibration: Separation of catchment response output into subflows
- Parameters were calibrated in subgroups corresponding the different processes behind each calibration objective
- Sequential Uncertainty Fitting (SUFI-2) and manual calibration maximizing Nash-Sutcliffe efficiency

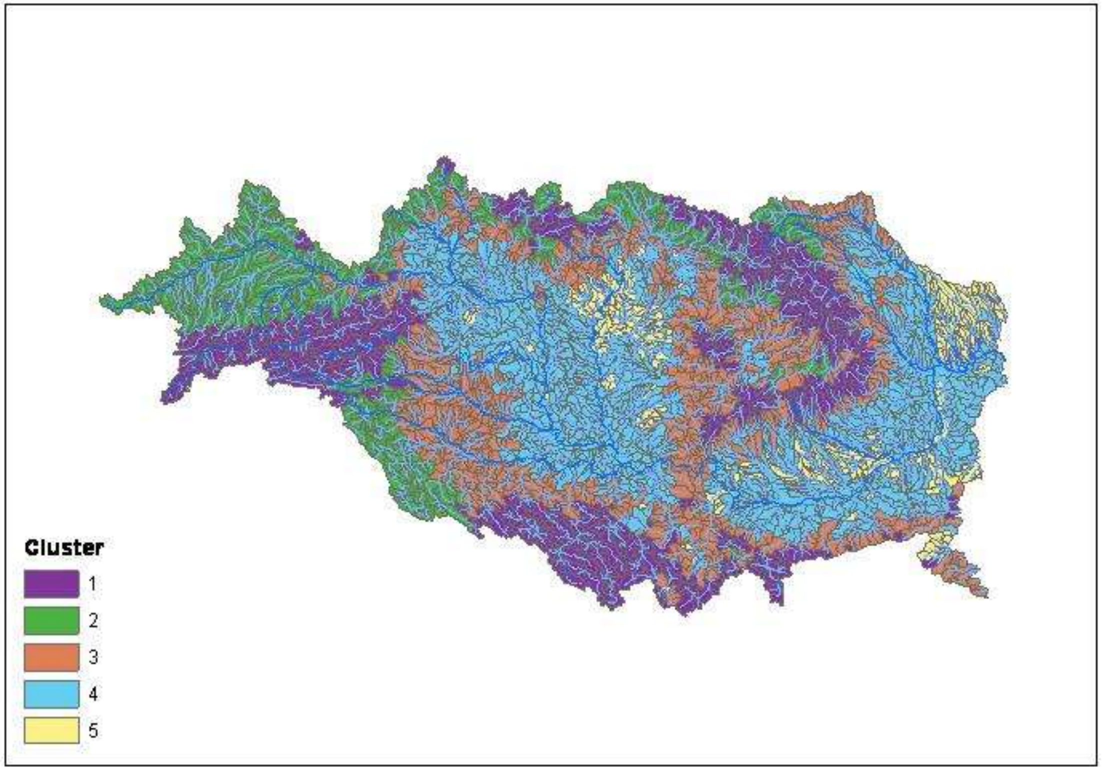
MODELLING PROTOCOL

1. Derive most relevant catchment characteristics for cluster analysis of hydrological regions using PCA
2. Define hydrological regions using clustering
3. Perform Sensitivity Analysis at subbasin level to select significant parameters for calibration
4. Select representative catchments of each region
5. Perform multi-objective calibration to obtain a set of calibrated parameters for each region
6. Extrapolate the set of calibrated parameters in the corresponding hydrological region.

RESULTS – Hydrological regionalization

Variables
Average elevation
Median slope
Clay content
Annual precipitation
Average temperature
Annual potential evapotranspiration
Forest area



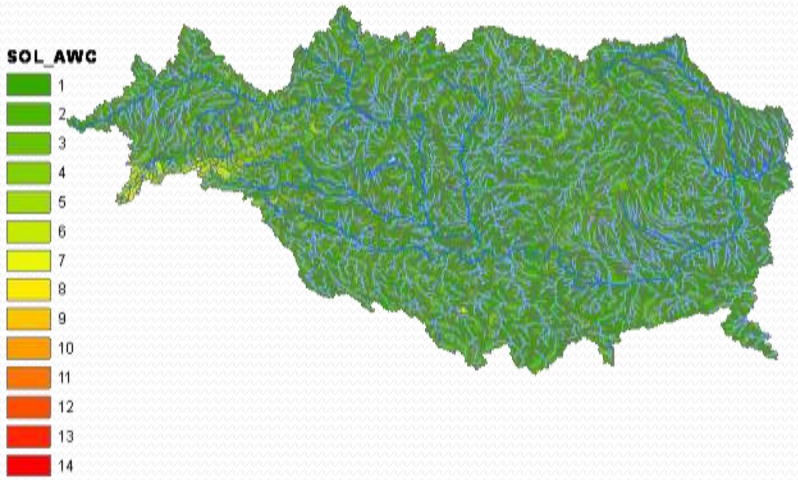


RESULTS – Calibration: Sensitivity Analysis

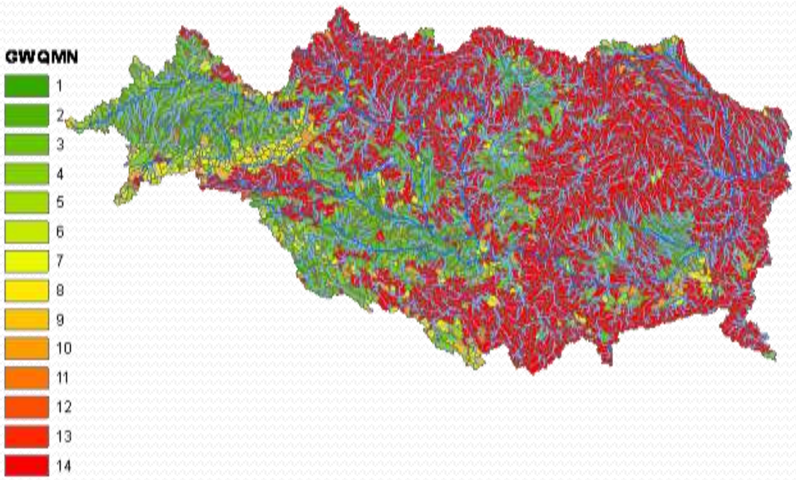
Parameter	Description	Process
ALPHA_BF	Baseflow alpha factor [d]	Baseflow
CN2	runoff curve number for moisture condition II	Surf runoff
GW_DELAY	Groundwater delay [d]	Baseflow
GWQMN	Thr. depth water in shallow aq. for return flow [mm]	Baseflow
RCHRG_DP	Groundwater recharge to deep aquifer [fr]	Baseflow
REVAPMN	Thr. depth water in shallow aq. for revap [mm]	Baseflow
SFTMP	Snowfall temperature [ºC]	Snow
SMFMN	Min melt rate for snow on Dec 21 [mm ºC-1 d-1]	Snow
SMFMX	Min melt rate for snow on Jun 21 [mm ºC-1 d-1]	Snow
SMTMP	Snow melt base temperature	Snow
SOL_AWC	Available water capacity of the soil layer [fr]	Surf runoff
SOL_K	Saturated hydraulic conductivity [mm h-1]	Surf runoff
SURLAG	Surface runoff lag time [d]	Surf runoff
TIMP	Snow pack temperature lag factor	Snow

Snow

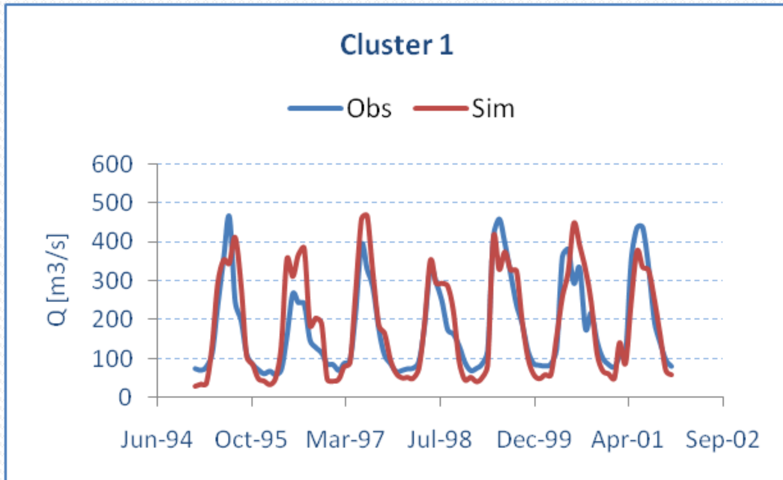
Surface runoff

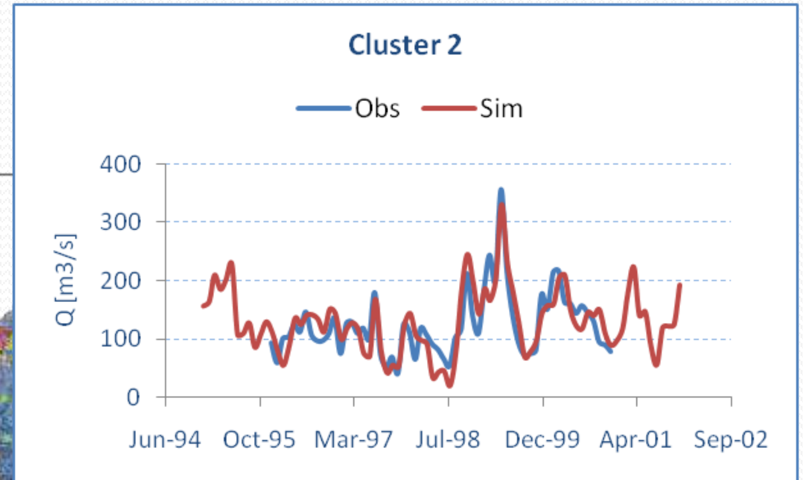


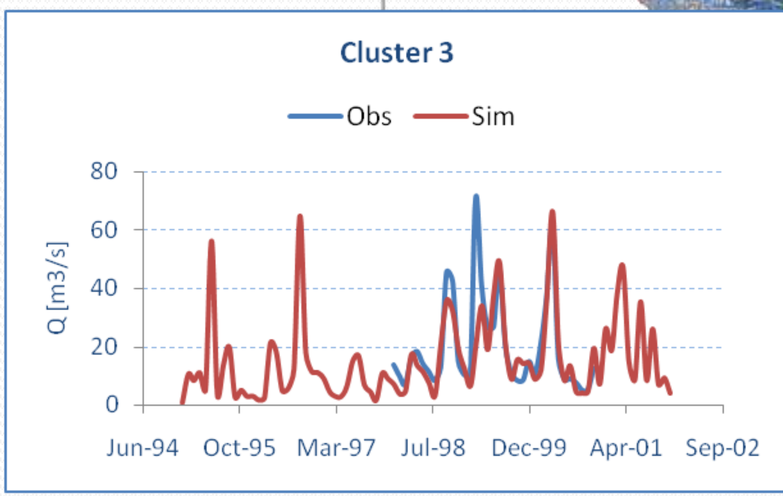
Baseflow

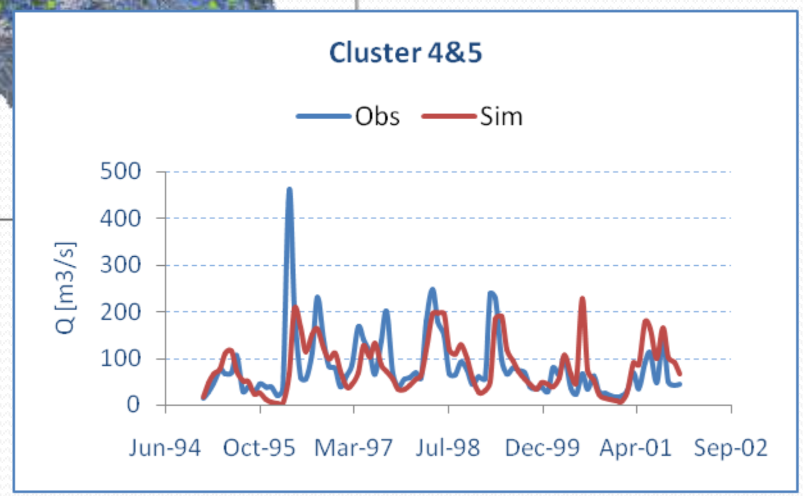


RESULTS – Calibration



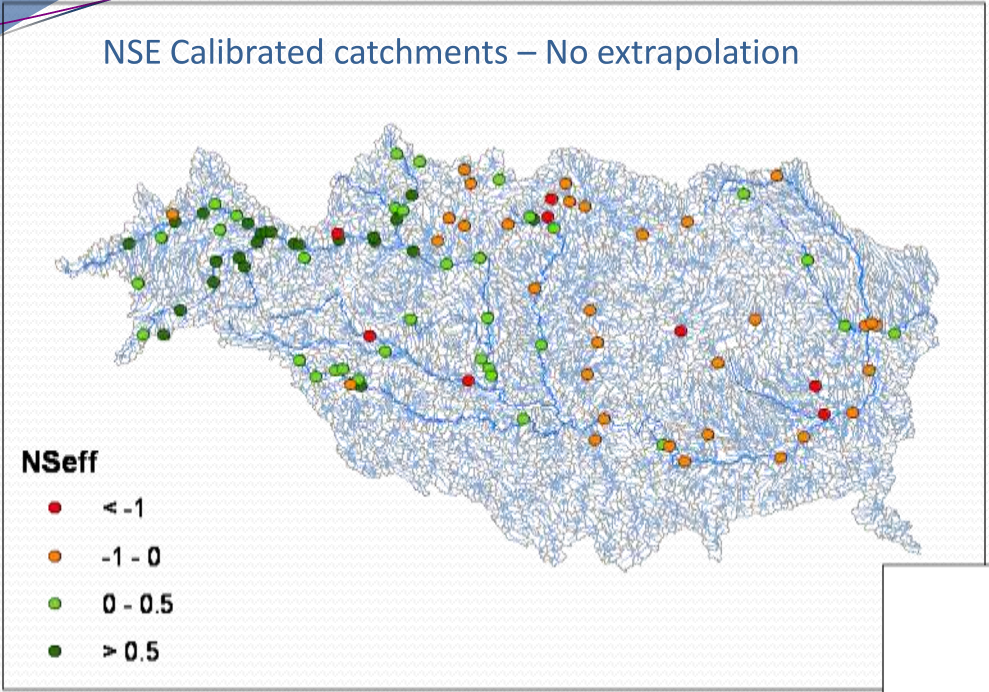


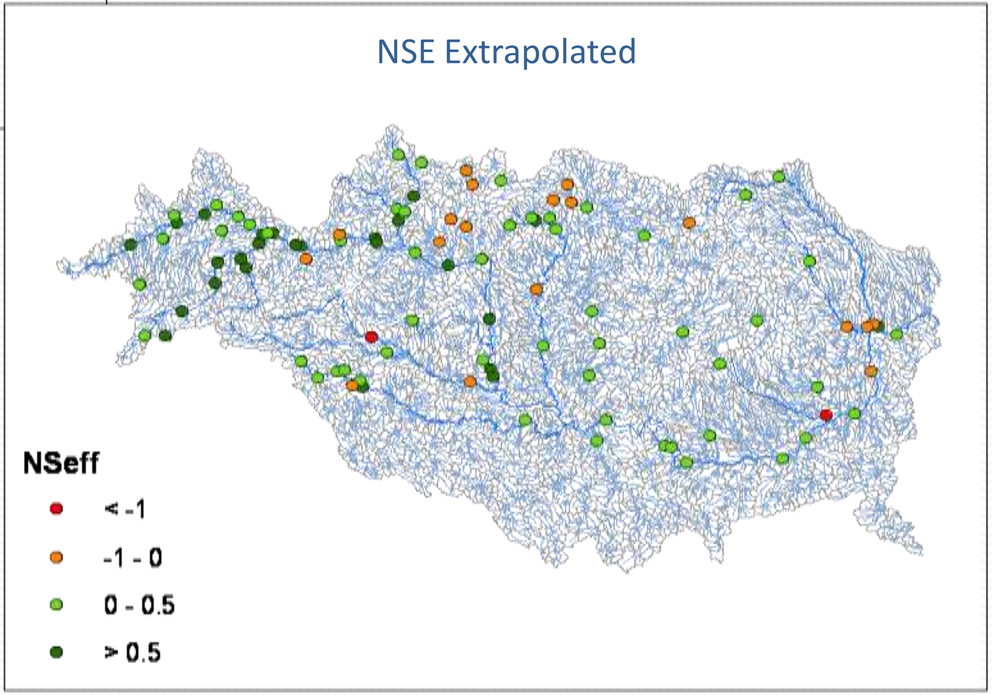




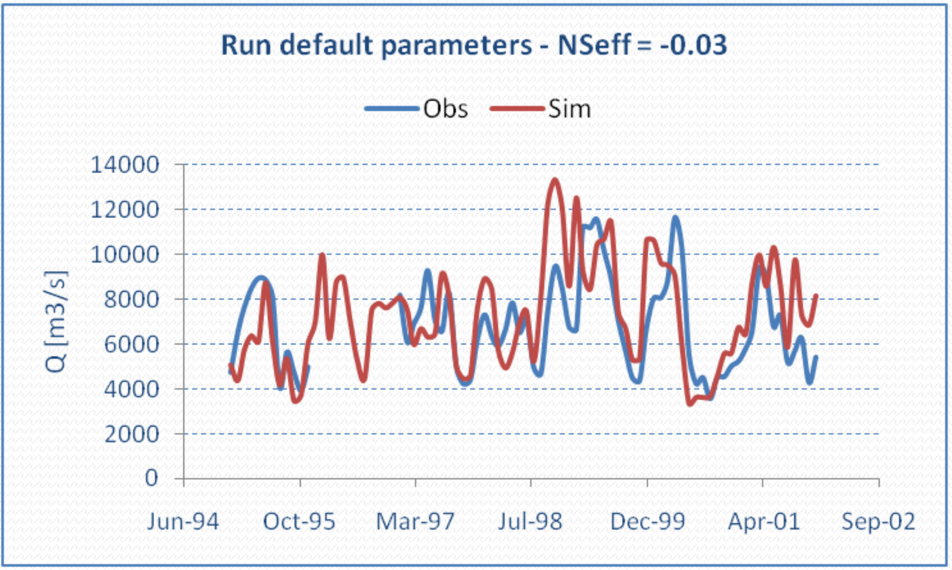
Cluster	1	2	3	4 & 5
R^2	0.77	0.73	0.64	0.23
bR^2	0.75	0.72	0.51	0.17
NSE	0.70	0.70	0.61	0.14

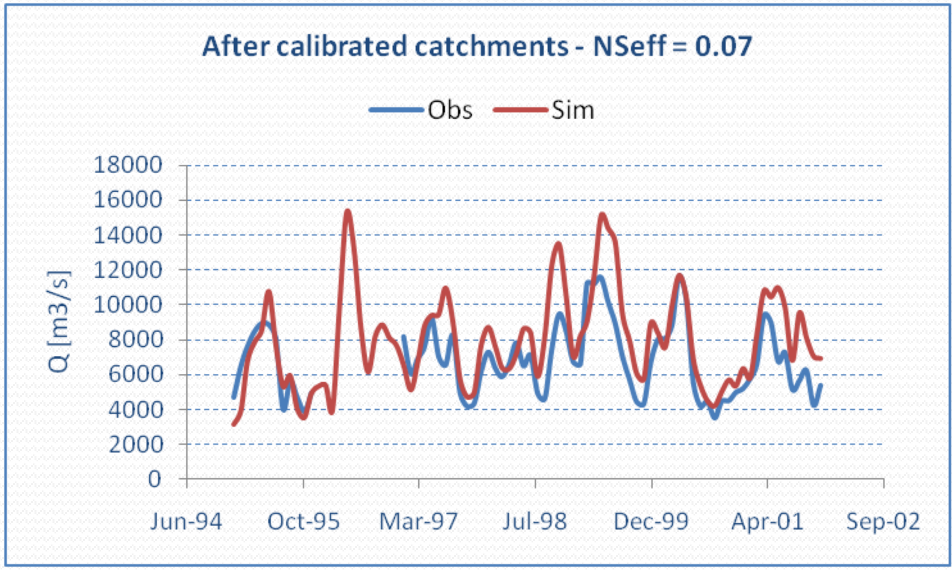
RESULTS – Calibration

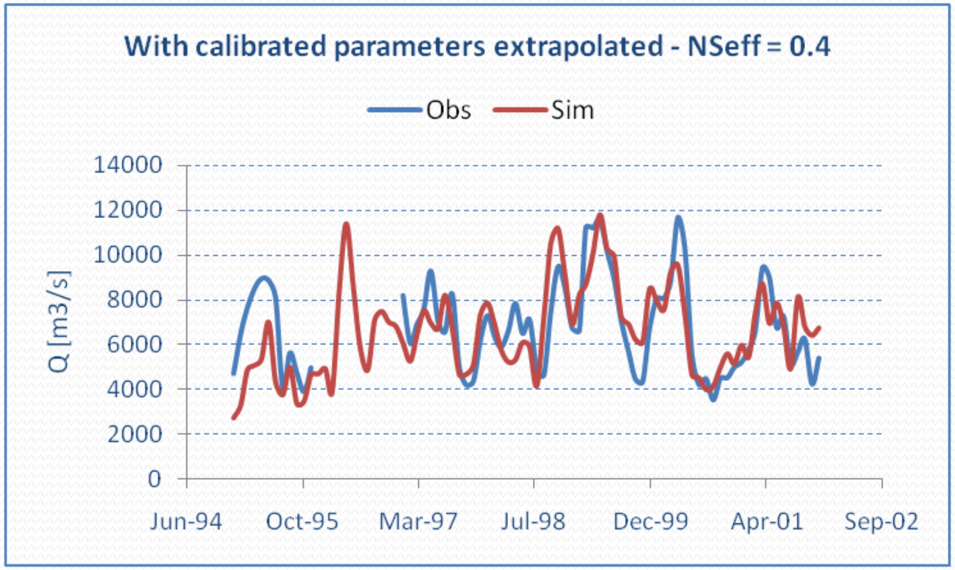




RESULTS – Calibration







CONCLUSIONS AND COMMENTS

- Development of protocol to simulate large scale hydrological systems using SWAT
  - Hydrological regionalization
  - Calibration transparency
- Sensitivity analysis at subbasin level was successfully implemented, as well as multi-objective calibration, which significantly improved calibration transparency.
- Hydrological regionalization using PCA and cluster analysis resulted in a clear improvement in model performance for the Danube.
- Correspondence between sensitivity maps and cluster results.
- Current version of SWAT: uniform parameters for basin.

Thank you

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