A large-scale and fine resolution SWAT model for an assessment of isolated climate change impact on unaltered flow regimes in Central Eastern Europe

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3. MET Norway
4. Institute for Agricultural and Forest Environment, Polish Academy of Sciences

CHASE-PL project

- CHASE-PL: Climate change impact assessment for selected sectors in Poland
- Climate Change thematic area of the Polish Norwegian Research Programme
- Timeline 2014-2016
- Partners: Institute for Agricultural and Forest Environment PAS (lead), MET Norway, WULS-SGGW

POLISH-NORWEGIAN RESEARCH PROGRAMME

Meteorologisk institutt

SZKOŁA GŁÓWNA GOSPODARSTWA WIEJSKIEGO W WARSZAWIE

Work packages

WP1 - Change detection in observed climate of Poland, at a range of scales (IAFE)

WP2 – Projections of climate variability and change for Poland, comparison with control period (MET.no)

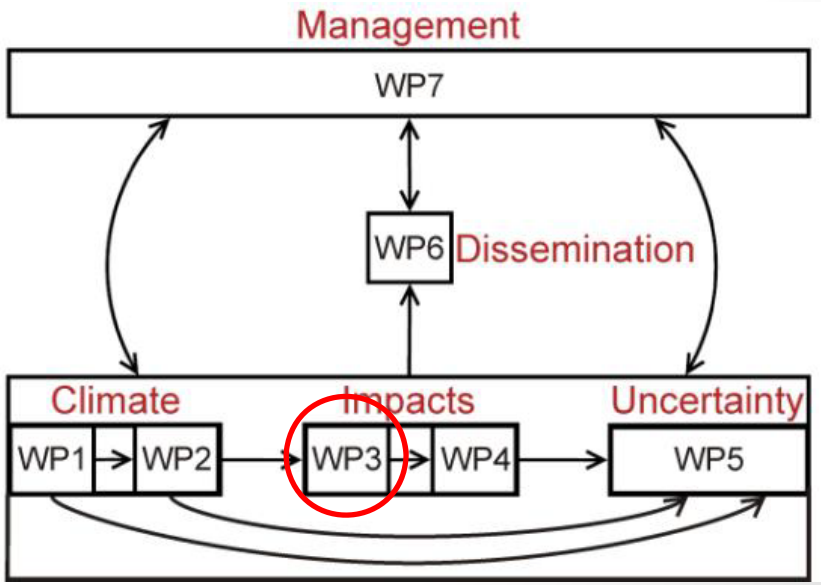
WP3 – **Model-based assessment of climate change impacts in the Vistula and the Odra basins (WULS)**

WP4 – Index-based assessment of climate change impacts on ecosystems and agriculture (WULS)

WP5 – Uncertainty in observations, understanding and projections – system framework (MET.no)

WP6 – Promotion and dissemination (**Integrated Web Mapping System**)

WP7 – Project management (IAFE)



GCM-RCM combinations of scenarios (EUROCORDEX)

SMHI-RCA4__EC-EARTH
SMHI-RCA4__CNRM-CERFACS-CNRM-CM5
SMHI-RCA4__MPI-M-MPI-ESM
SMHI-RCA4__MOHC-HadGEM2-ES
SMHI-RCA4__IPSL-IPSL-CM5A-MR

CLMcom-CCLM4-8-17__ICHEC-EC-EARTH
CLMcom-CCLM4-8-17__CNRM-CERFACS-CNRM-CM5
CLMcom-CCLM4-8-17__MPI-M-MPI-ESM-LR
CLMcom-CCLM4-8-17__MOHC-HadGEM2-ES

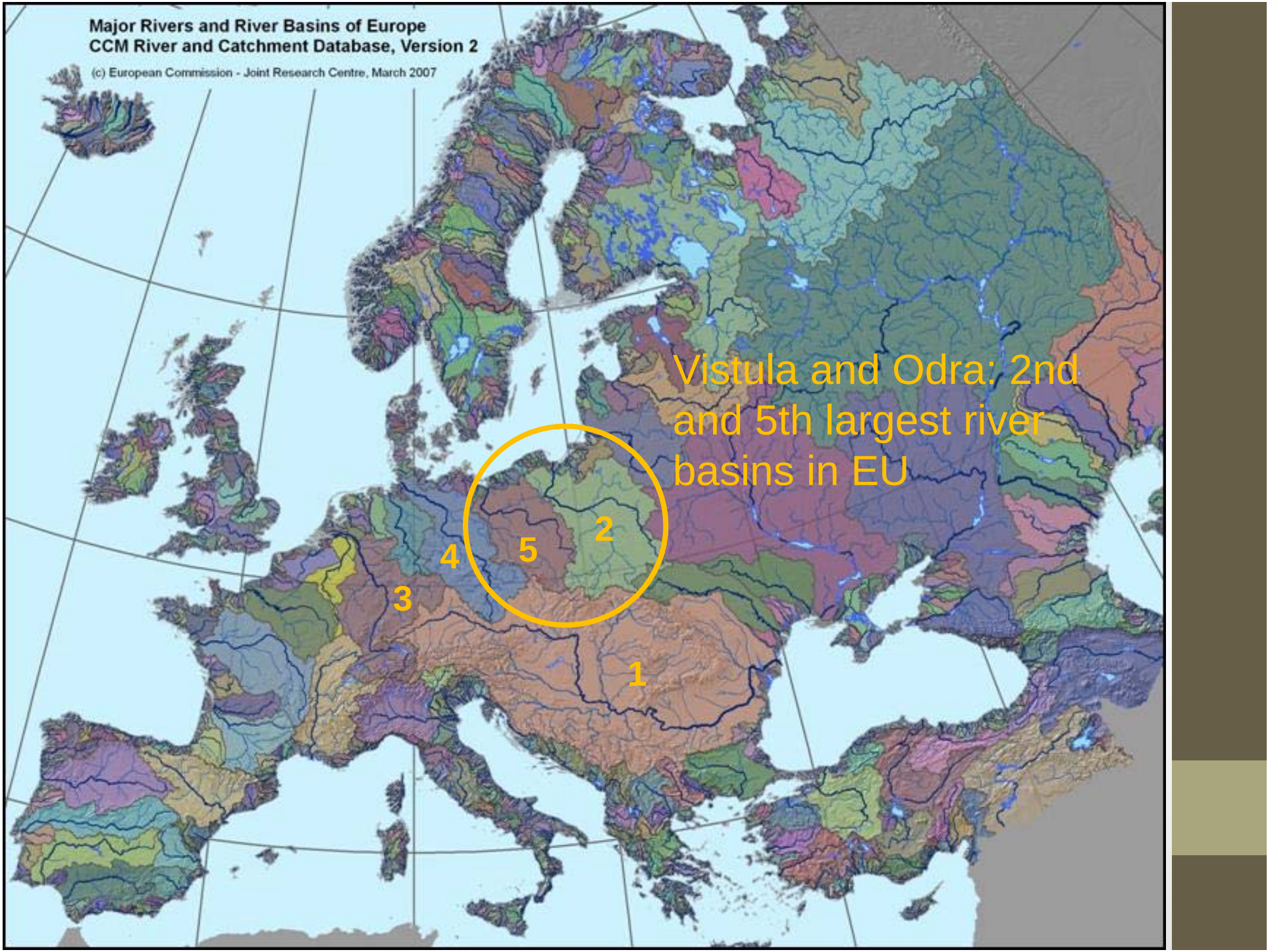
DMI-HIRHAM5__ICHEC-EC-EARTH

KNMI-RACMO22E__ICHEC-EC-EARTH

Bias correction (quantile mapping method) ongoing!

WP3 main objective

- Model-based assessment of climate change impacts in the Vistula and the Odra basins
- Two-level approach of impact assessment
  - In large-scale focus on: water balance, river flows
  - In meso-scale focus additionally on: water quality, crop yields, environmental flows
  - In large-scale: broad spatial overview of impacts and identification of hot spots
  - In meso-scale : more in-depth process-oriented analysis + adaptation measures
- The SWAT model as the main modelling tool


Major Rivers and River Basins of Europe
CCM River and Catchment Database, Version 2
(c) European Commission - Joint Research Centre, March 2007
Vistula and Odra: 2nd and 5th largest river basins in EU
1
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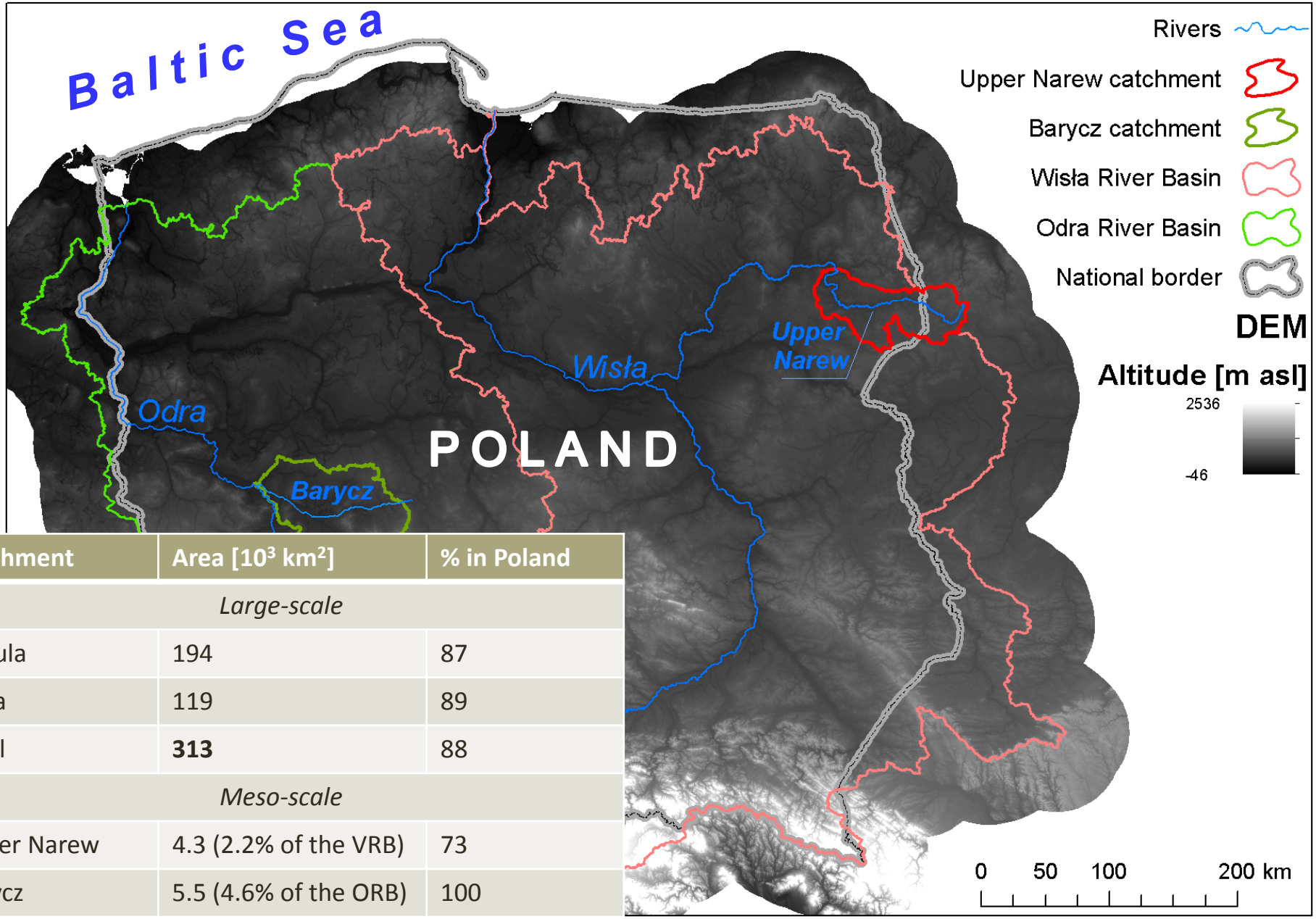
Study area: Vistula and Odra river basins



Catchment	Area [10^3 km^2]	% in Poland
Large-scale		
Vistula	194	87
Odra	119	89
Total	**313**	88
Meso-scale		
Upper Narew	4.3 (2.2% of the VRB)	73
Barycz	5.5 (4.6% of the ORB)	100

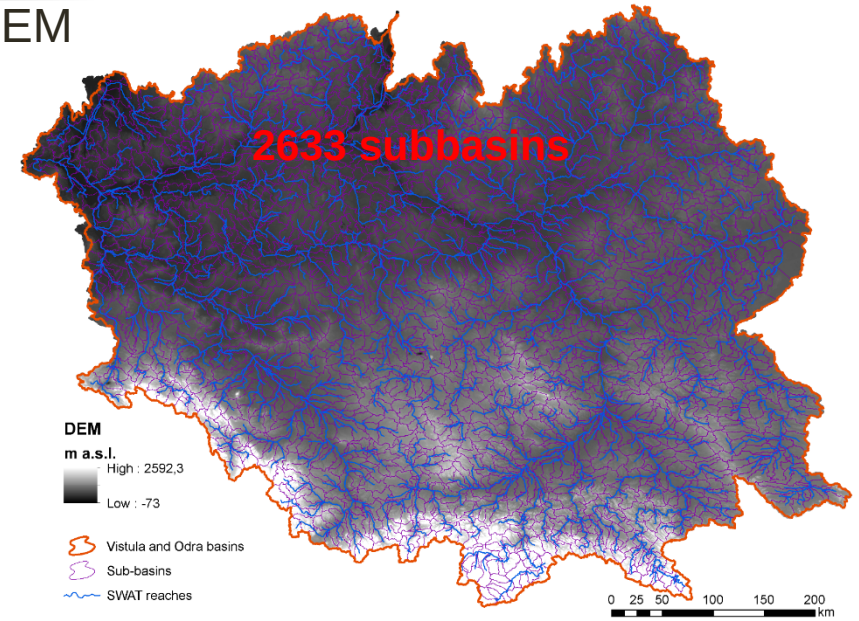
Overview of data sources for model inputs

Type of input	Poland	Outside Poland
DEM	Created based on contour lines, scale 1:25,000, 40m res.	SRTM v4.1 90 m res.
Hydrographic network	MPHP (Hydrographic Map of Poland), scale 1:50,000	CCM River and Catchment Database, version 2.1
Land cover	CLC2006, Imperviousness2012 (EEA), district-level crop statistics (GUS)	CLC2006, MODIS Land Cover & Imperviousness2012 (EEA)
Soils	Soil map from IUNG-PIB, scale 1:500,000	Harmonized World Soil Database v 1.2
Climate data 1	Observed data from IMGW-PIB 1951-2013	Observed data from DWD, ECAD, NOAA NCDC 1951-2013
Climate data 2	WATCH WFD (ERA-40) 1900-1978	WFDEI (ERA Interim) 1979-2012

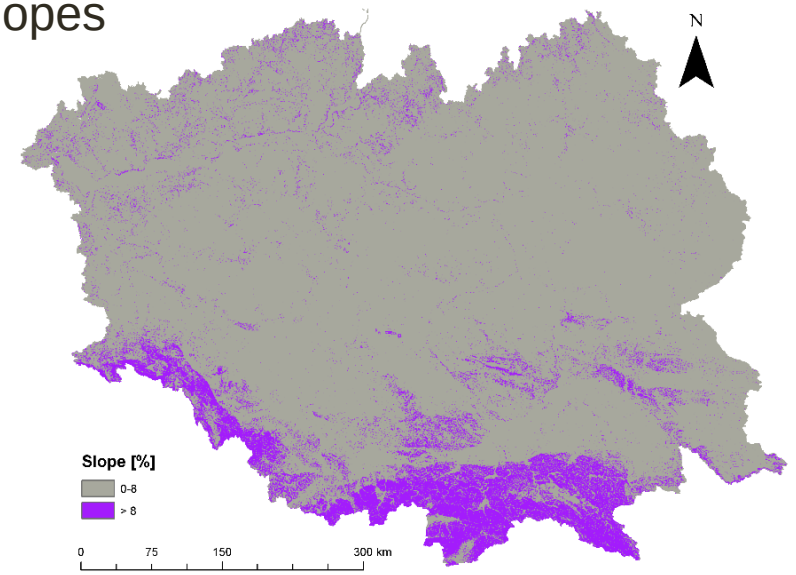
Development of high-resolution gridded temperature and precipitation datasets for modelling

Input maps

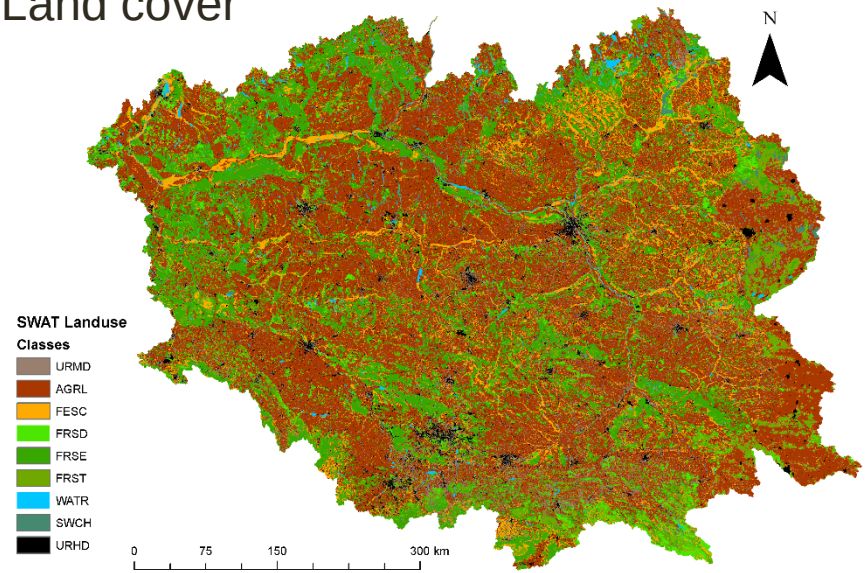
DEM



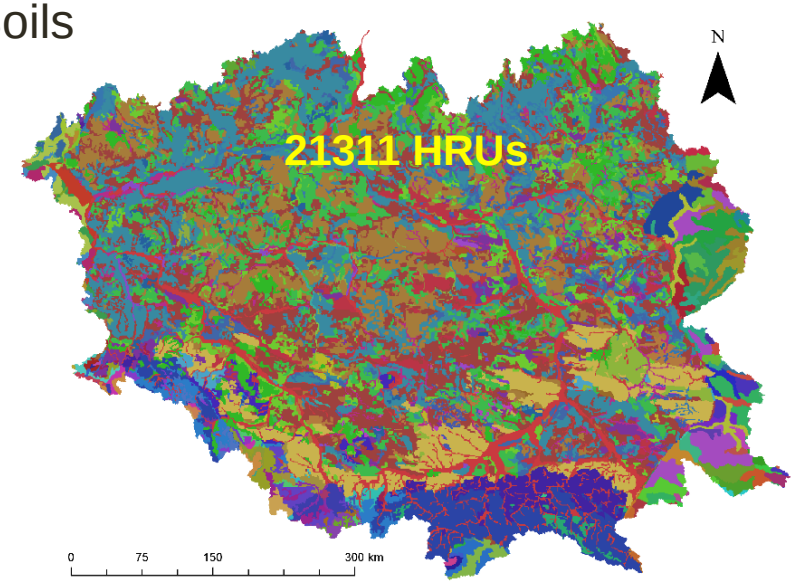
Slopes



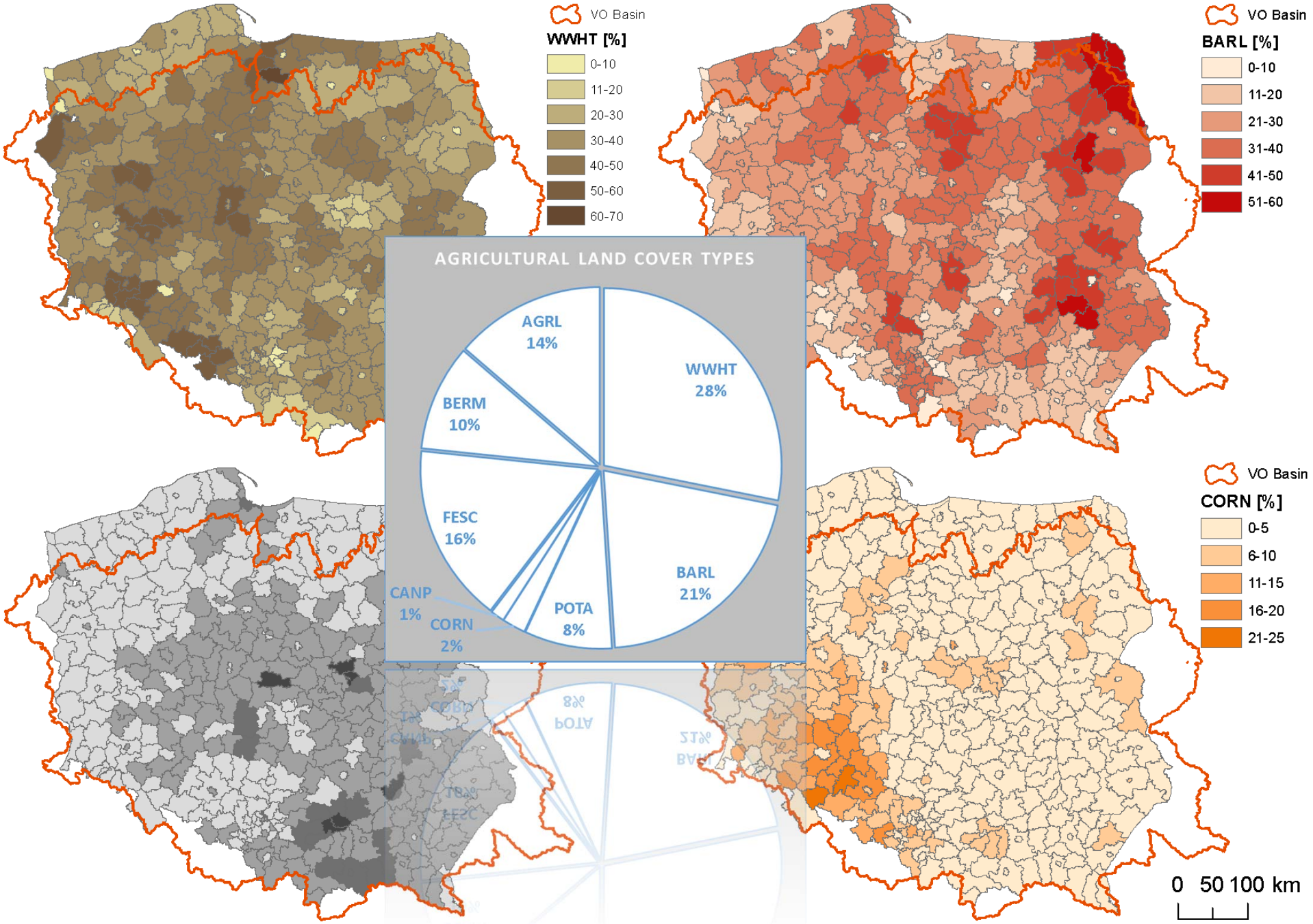
Land cover



Soils



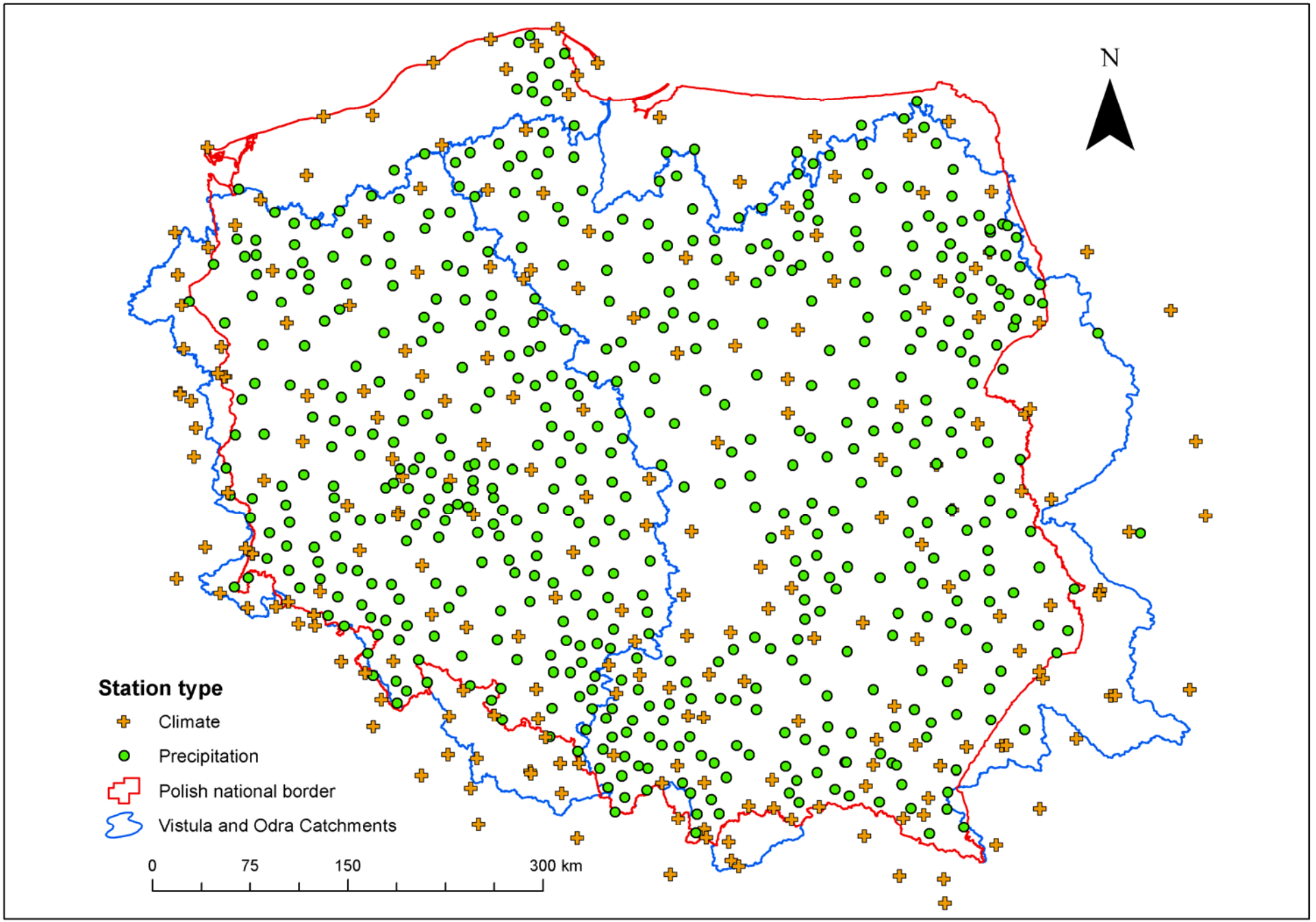
Land cover refinement: main crops (2000 Census data)



Development of gridded temperature and precipitation datasets for modelling - overview

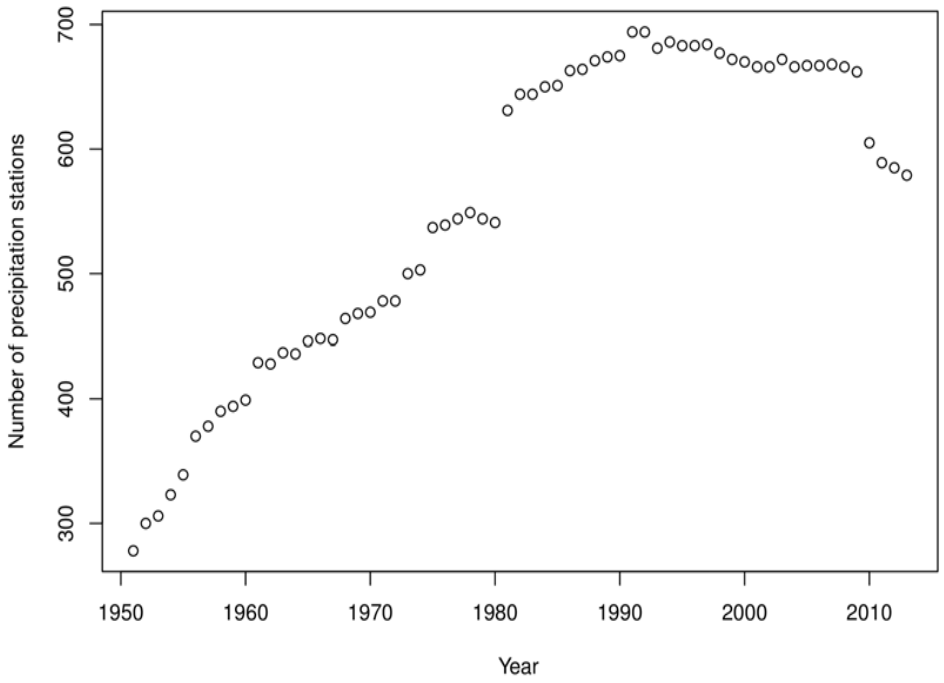
Item	Minimum and maximum temperature	Precipitation
Domain	Poland + Vistula and Odra basins	
Data sources	• IMGW-PIB – Polish stations • DWD - German and Czech stations • ECAD, NOAA-NCDC – Slovak, Ukrainian and Belarusian stations	
Preprocessing	Quality assessment	Quality assessment Richter correction for precipitation undercatch
Interpolation method	Kriging with elevation as external drift	Combination of Universal Kriging and Indicator Kriging (for wet day probability estimation)
Library	R gstat	
Time frame	1951-2013	
Resolution	5 km grid in the projected coordinate system PUWG1992	
Output format	.tiff files (one file per variable per day)	
Cross validation	All stations, for each day. Both temporal and spatial scale	
SWAT input	Aggregation at subbasin level	

Temperature and precipitation stations network



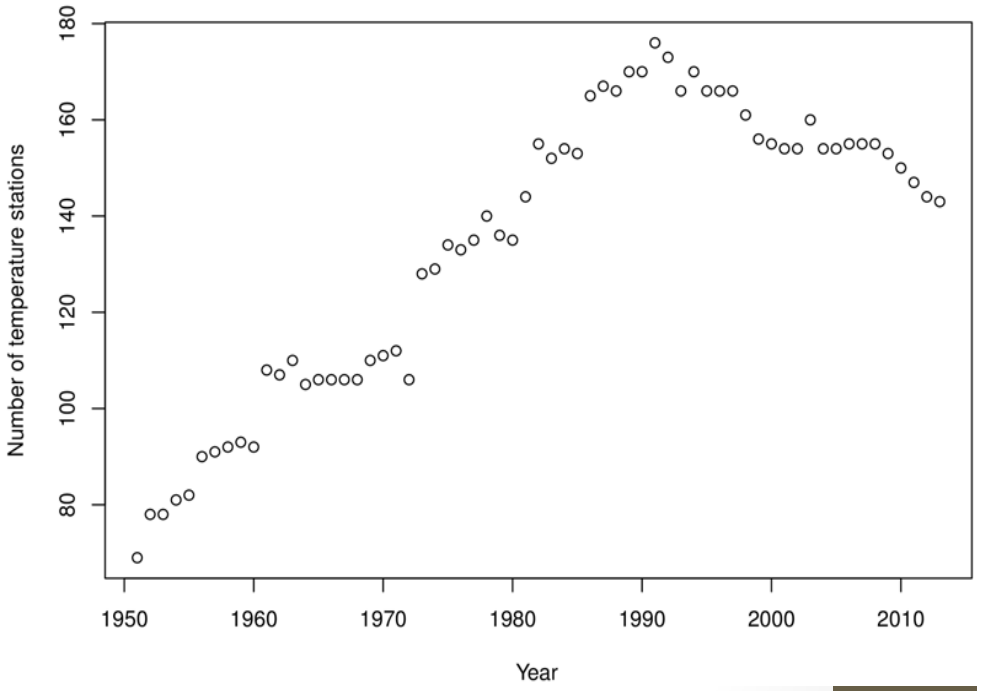
Number of stations with data: annual variability

Precipitation



Range: 300-700

Temperature

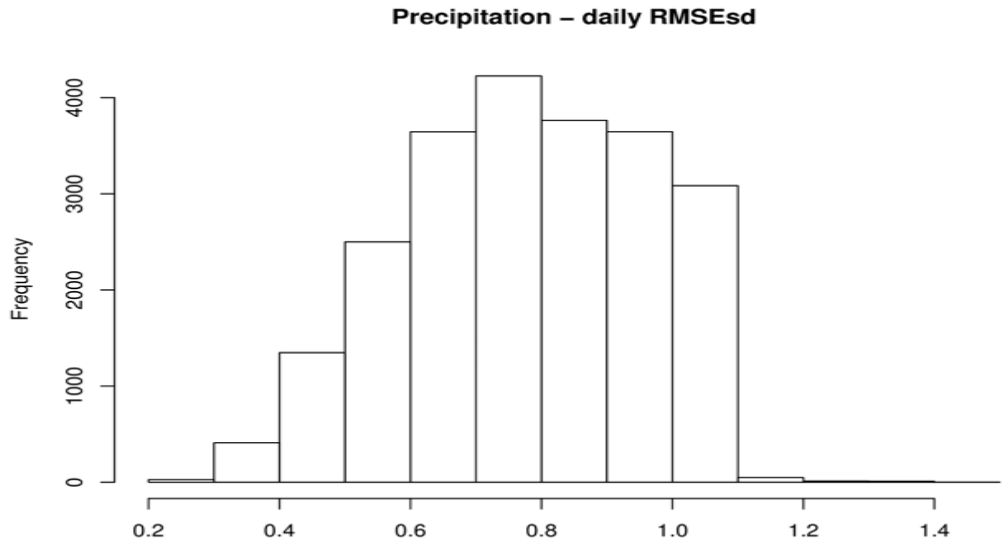


Range: 80-180

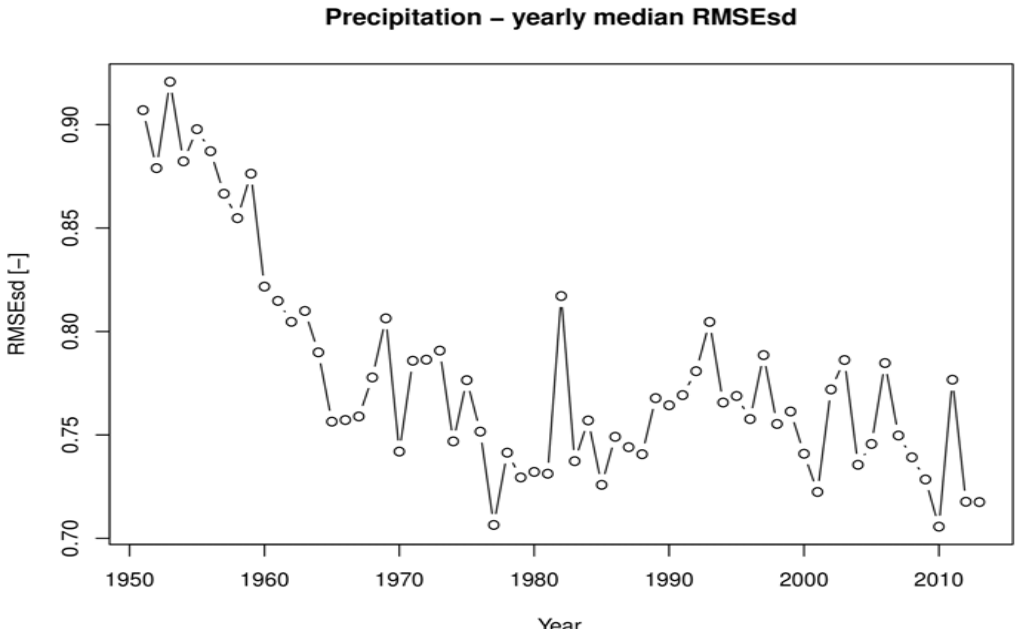
30-year baseline with the best coverage: 1982-2011

Cross validation of precipitation: standardized RMSE

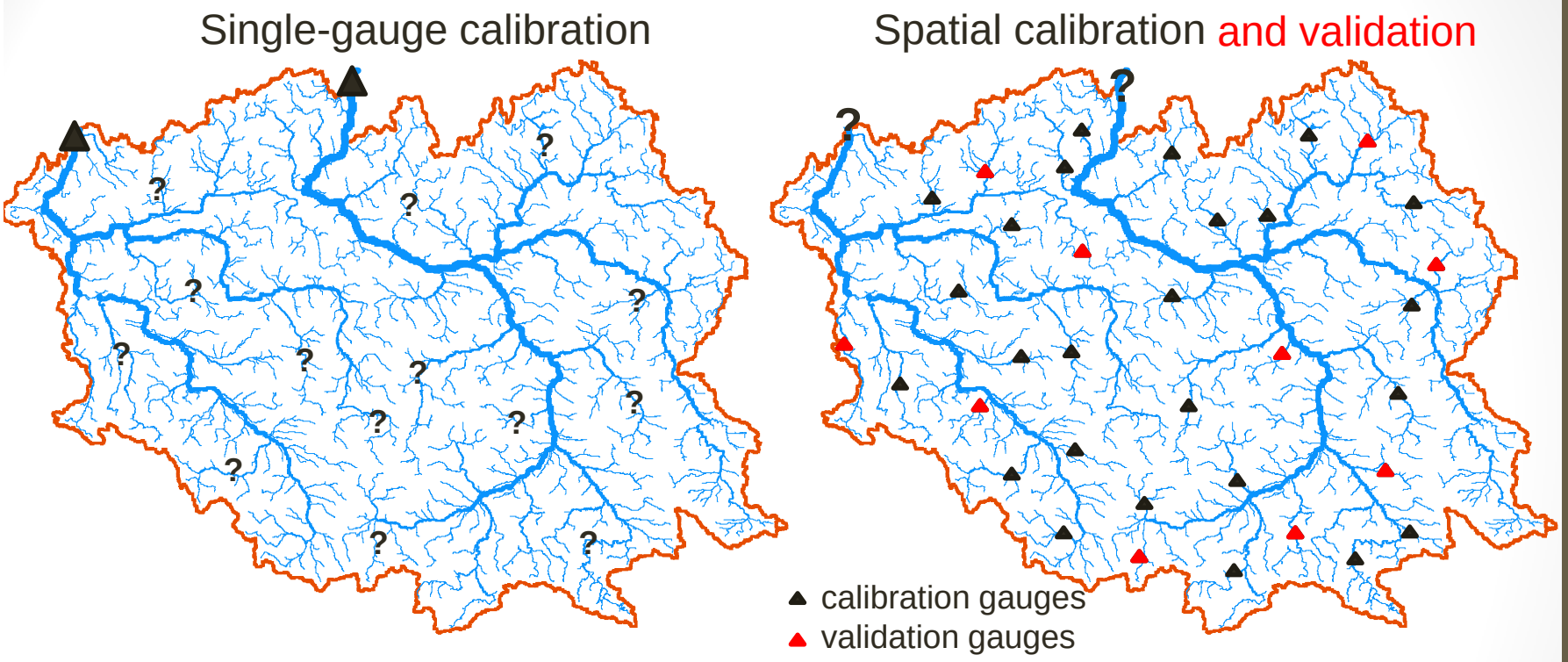
- Median range 0.7-0.8, with more than 85% of RMSE values not exceeding one standard deviation



- Negative correlation with the numer of available stations
- Errors depend on the density of the observation network



Calibration of large-scale models



- Unavoidable problem in calibration of large-scale models: water management
- In the context of climate change impact modelling, water management effects may distort pure climate change effects!

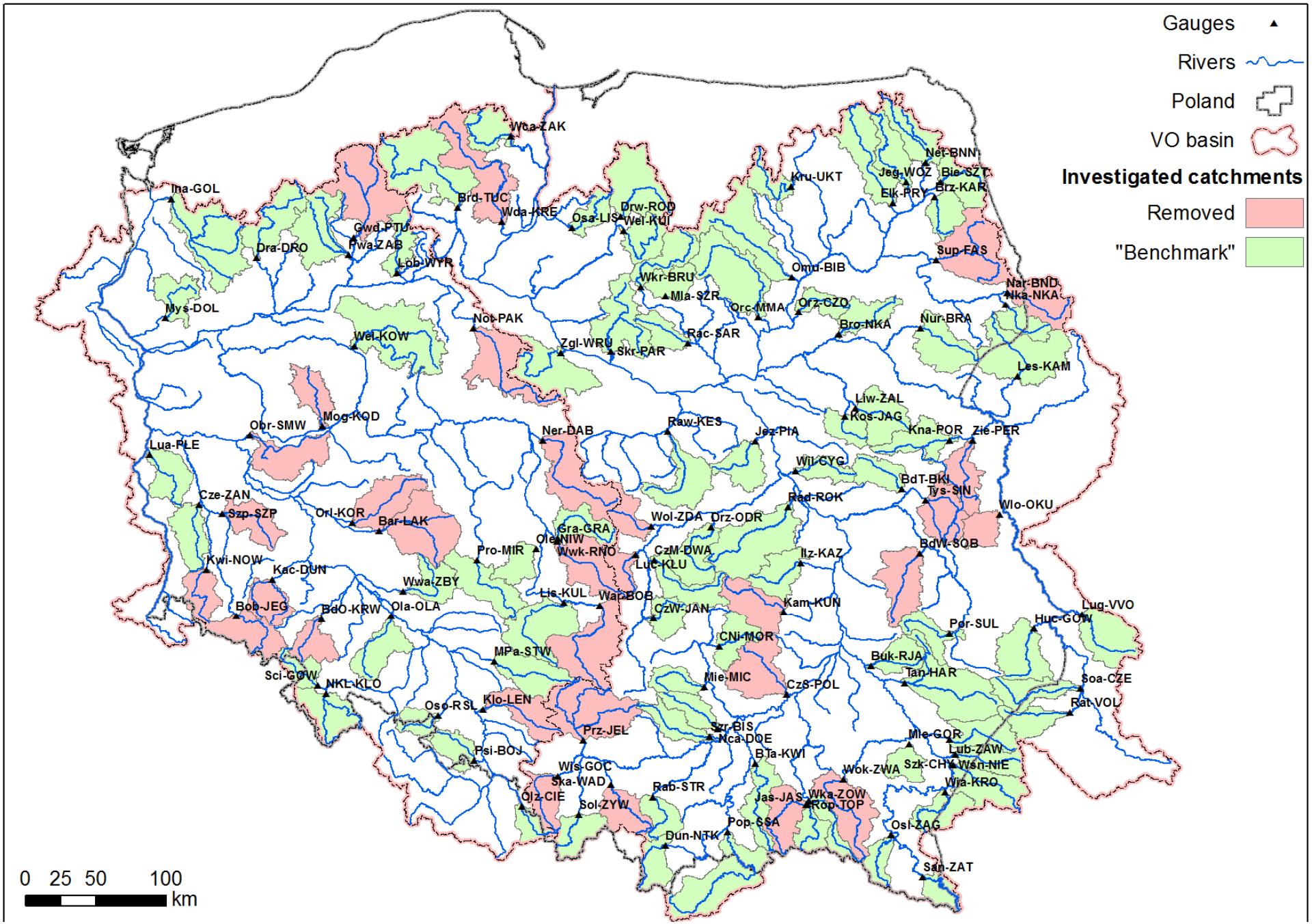
Large-scale model calibration approach

- The goal: investigate pure climate change effects (i.e. isolated from water management effects that can amplify or damp CC signal) in order to enable **fair spatial comparison of CC impacts**
- The approach: to focus model calibration on **near-natural sub-catchments =>** develop a model simulating “natural” flows
  1. Water management not considered in the model setup
  2. “Benchmark” (gauged) catchments selected for calibration/validation
  3. Optimising the multi-site calibration effort by a statistical approach involving the Indicators of Hydrologic Alteration, Principal Component Analysis and Cluster Analysis
  4. Regionalisation of optimal parameter values in order to simulate “natural” flows across the whole basin (future step)

Selection of „benchmark" catchments

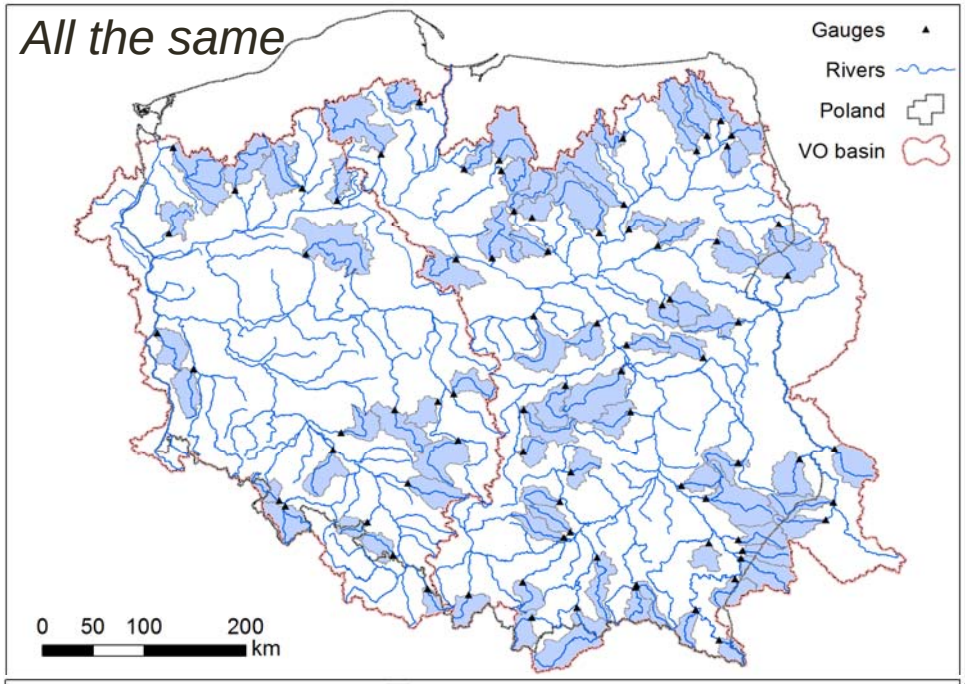
- "Benchmark" = near-natural, relatively undisturbed flow regime
- Initial pool contains 100+ **non-nested** gauged catchments (areas 500 – 3,000 km^2) with available (> 10 years) discharge data
- Selection of relatively unimpacted catchments using two approaches
  - Potential predictors of flow alterations selected and calculated in GIS, e.g. dam density; reservoir storage index, volume of water withdrawals, volume of point source discharges
  - Hydrograph screening (visual inspection)
- 80 "benchmark" catchments selected

Selection of "benchmark" catchments

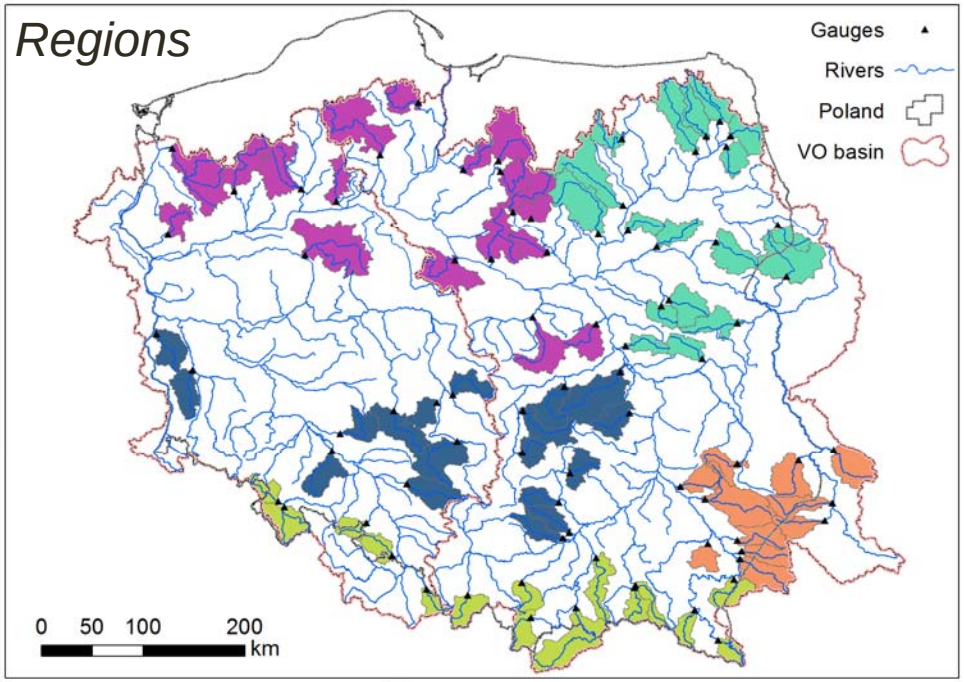


Spatial calibration (parametrisation) approaches

All the same



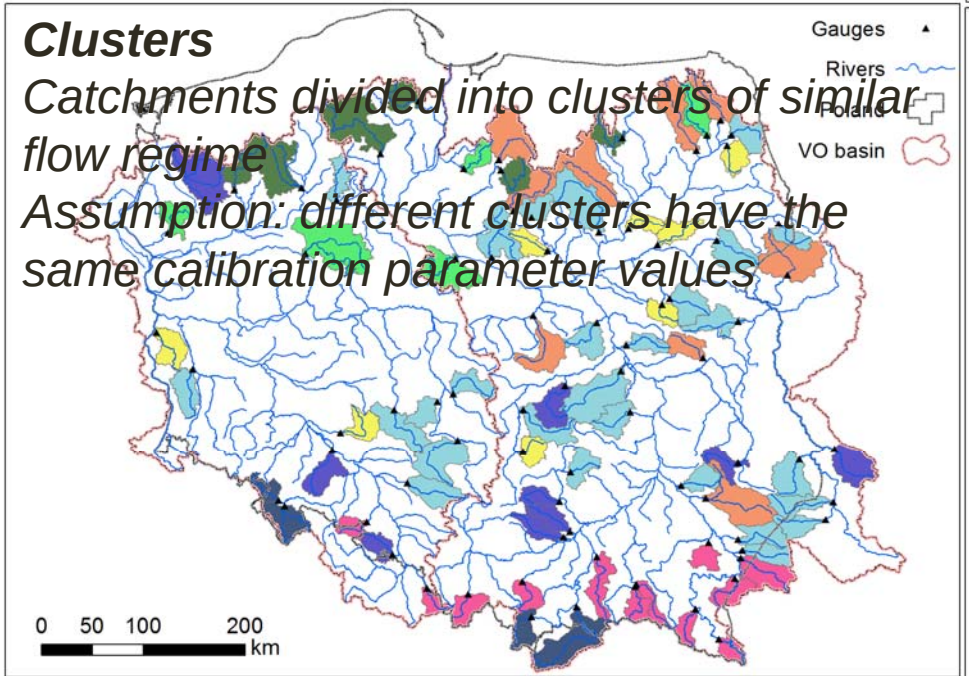
Regions



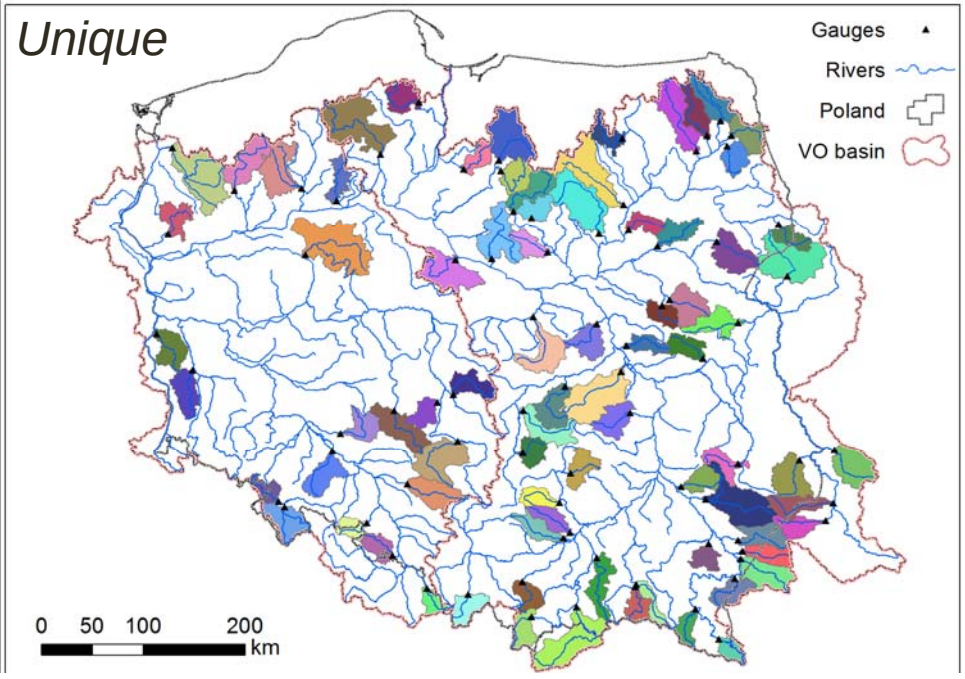
Clusters

Catchments divided into clusters of similar flow regime

Assumption: different clusters have the same calibration parameter values



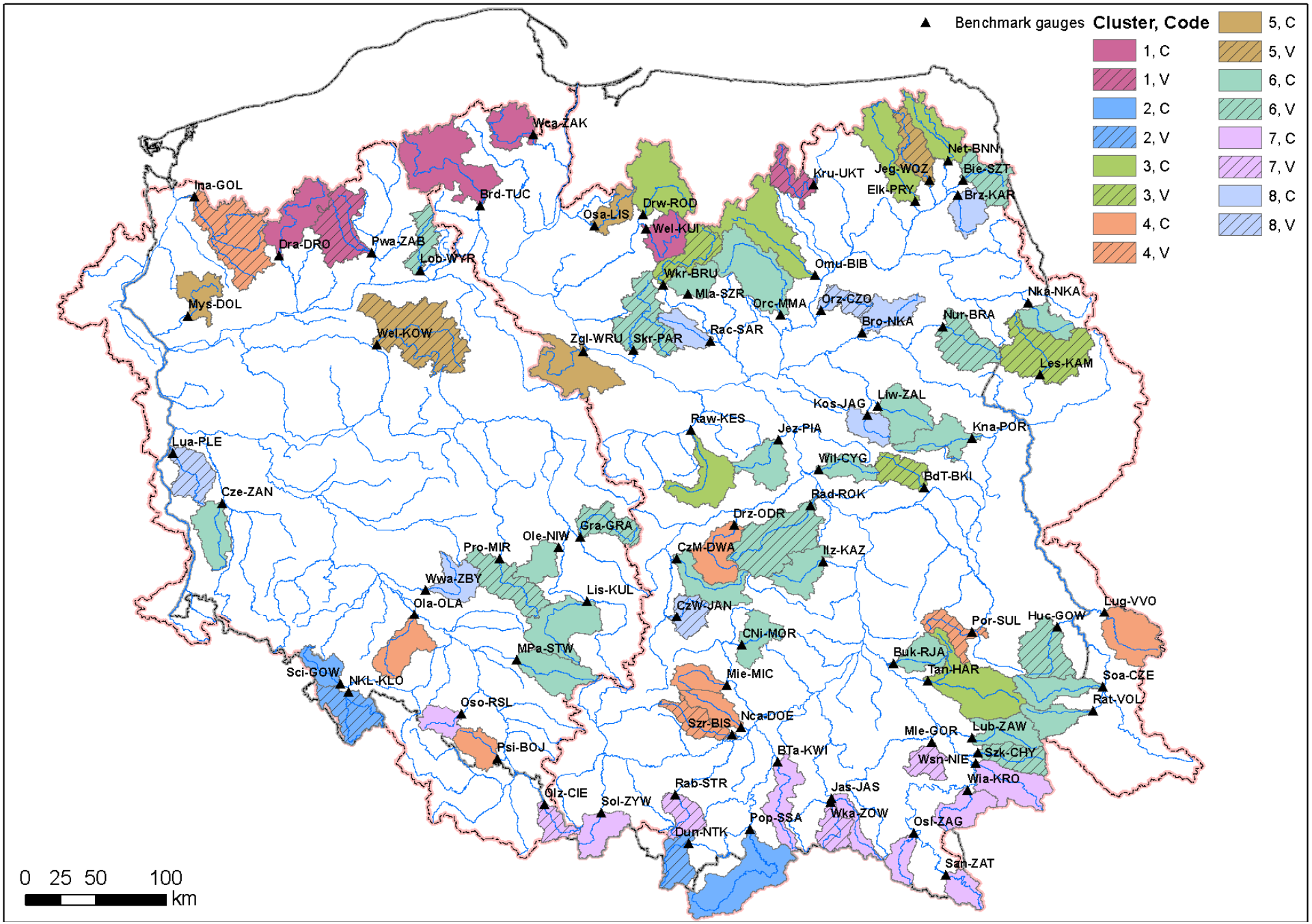
Unique

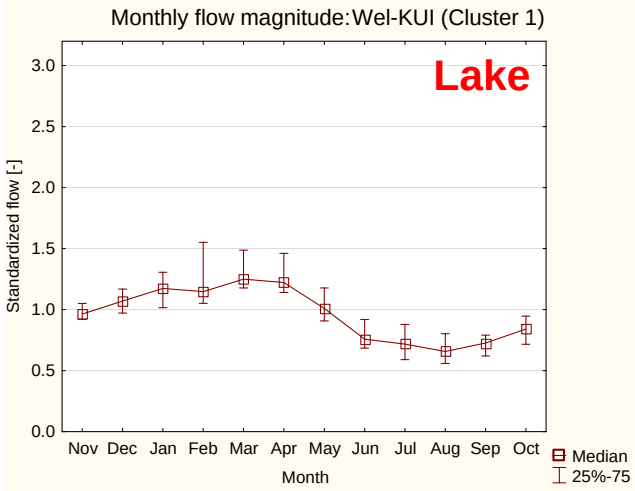


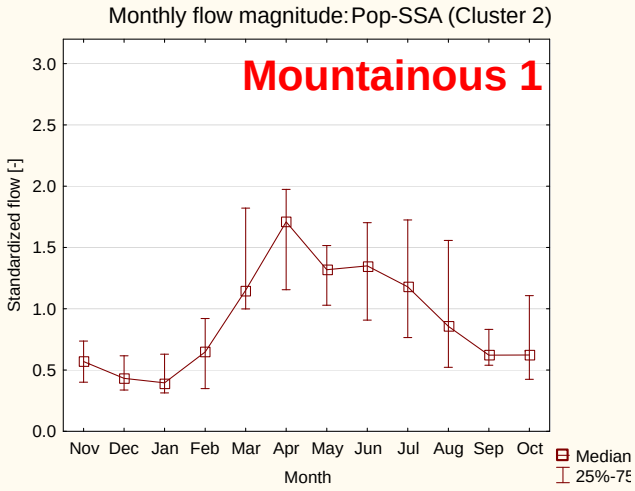
An approach for flow regime clustering for optimising calibration process

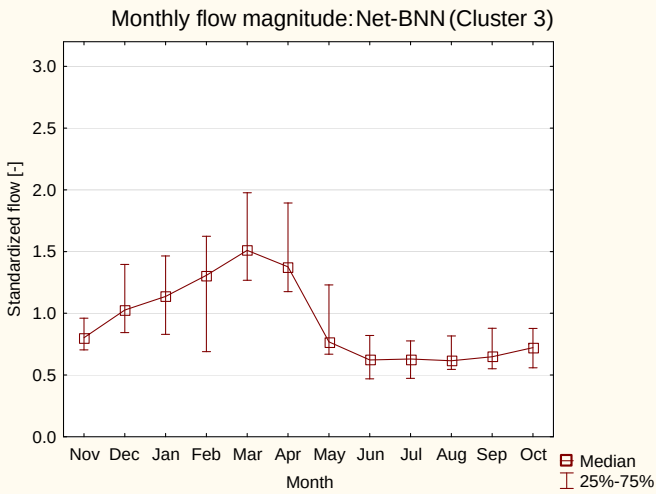
1. Major components of the flow regime (magnitude, extremes, duration, timing, rate of change) quantified using 67 Indicators of Hydrologic Alteration (IHAs) for 80 “benchmark” catchments for the period 1990-2009
2. Principal Component Analysis (PCA) applied in order to derive a parsimonious set of non-correlated synthetic indices that represent several uncorrelated dimensions of hydrological variability
3. Tree clustering applied to selected PCAs in order to join gauges into groups having similar flow regimes
4. Each cluster randomly divided into calibration and validation subsets
5. SWAT calibration/validation performed using SWAT-CUP SUFI2 separately for each cluster

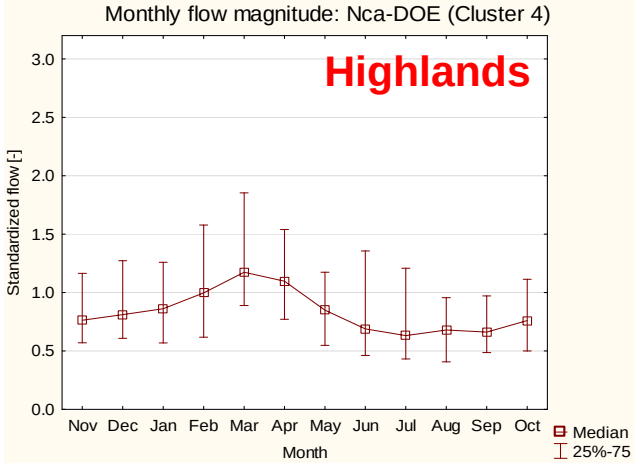
Flow regime clusters

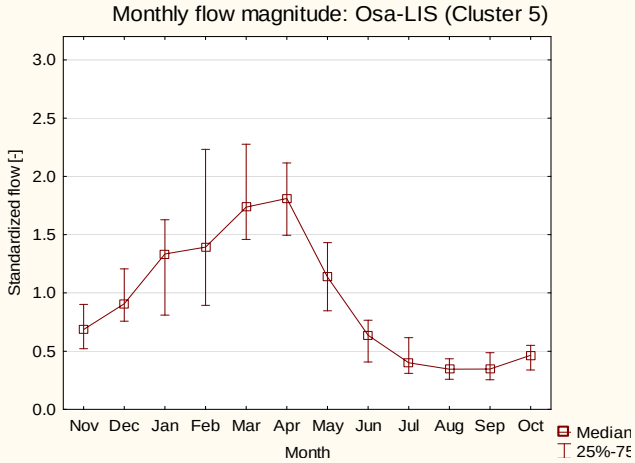


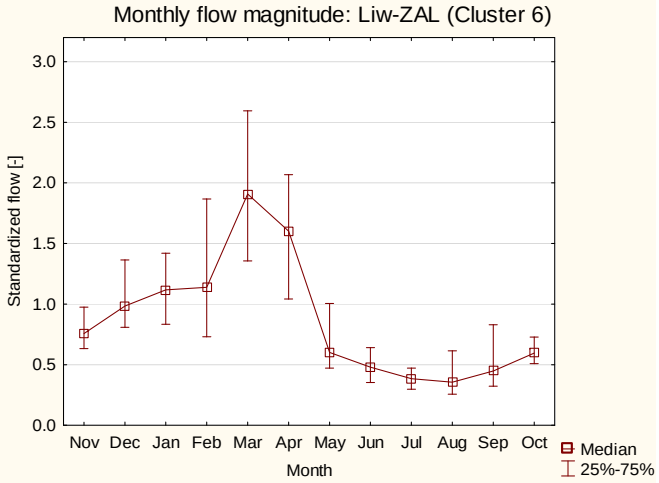


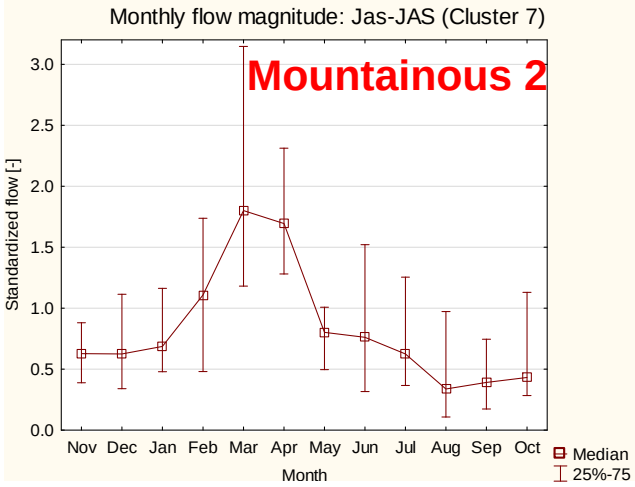


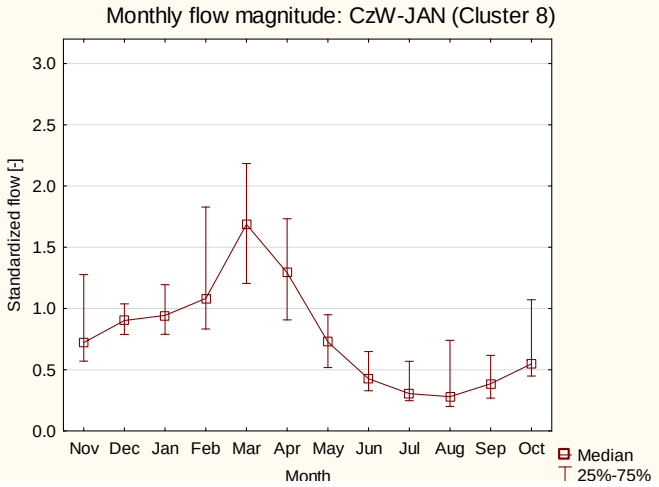






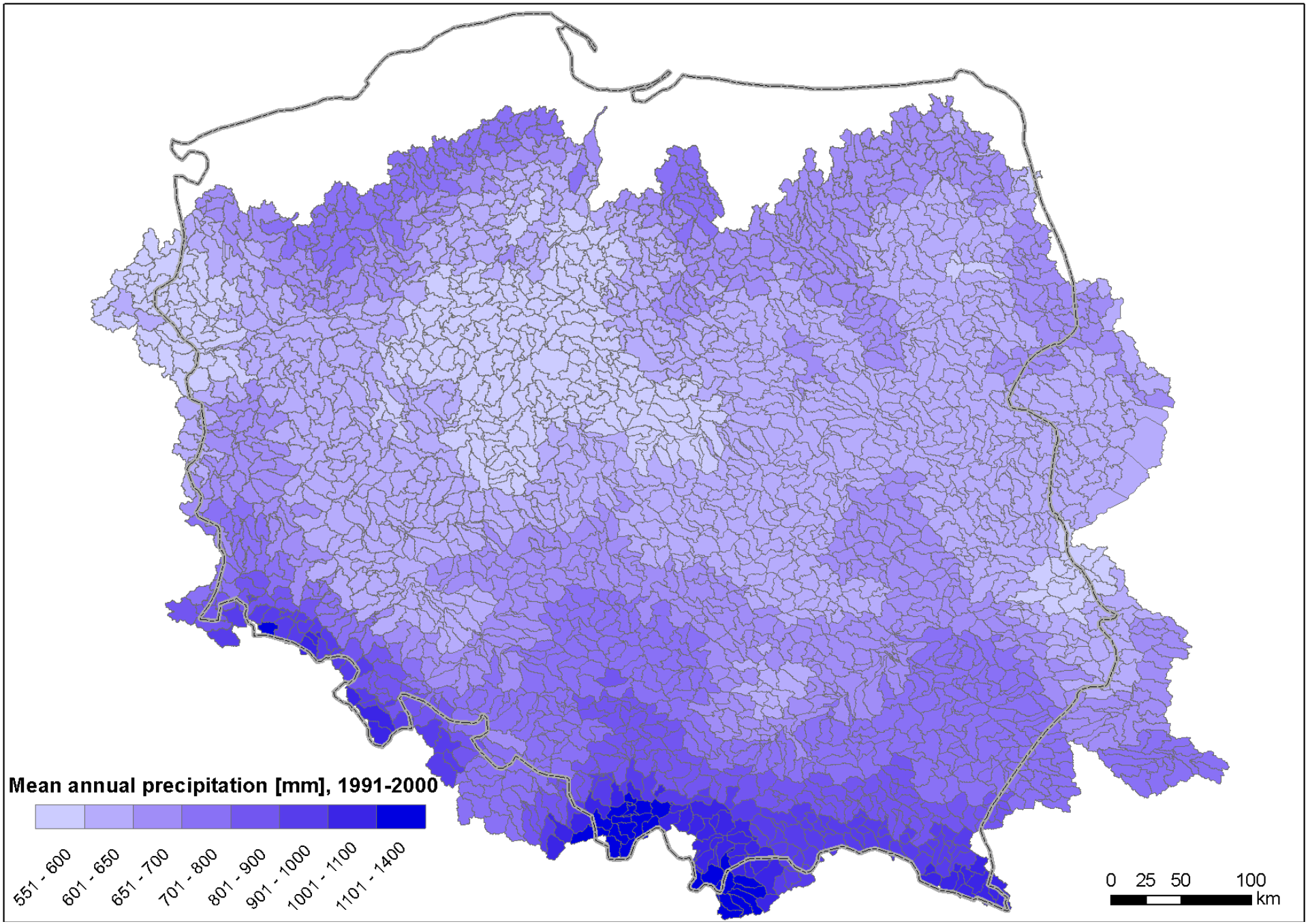




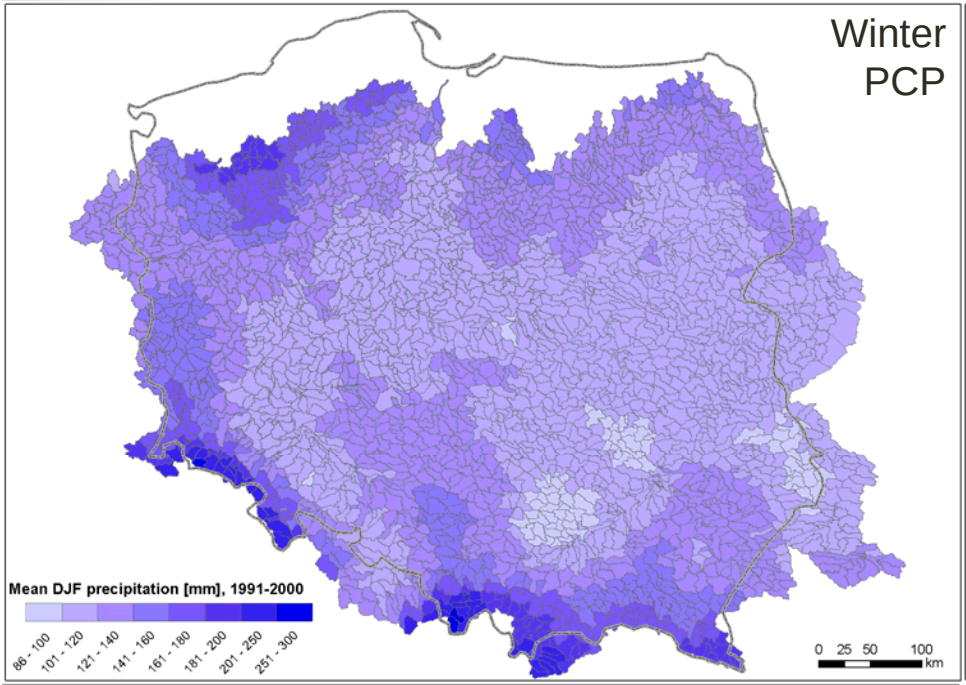


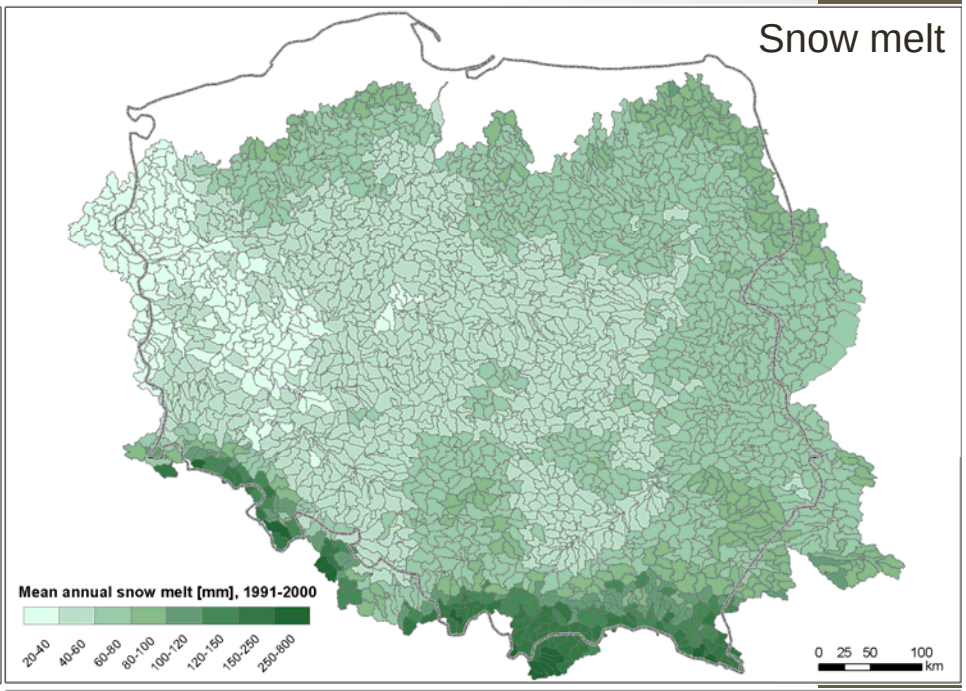
- Median (+/- IQR) monthly standardized flows
- One catchment per cluster

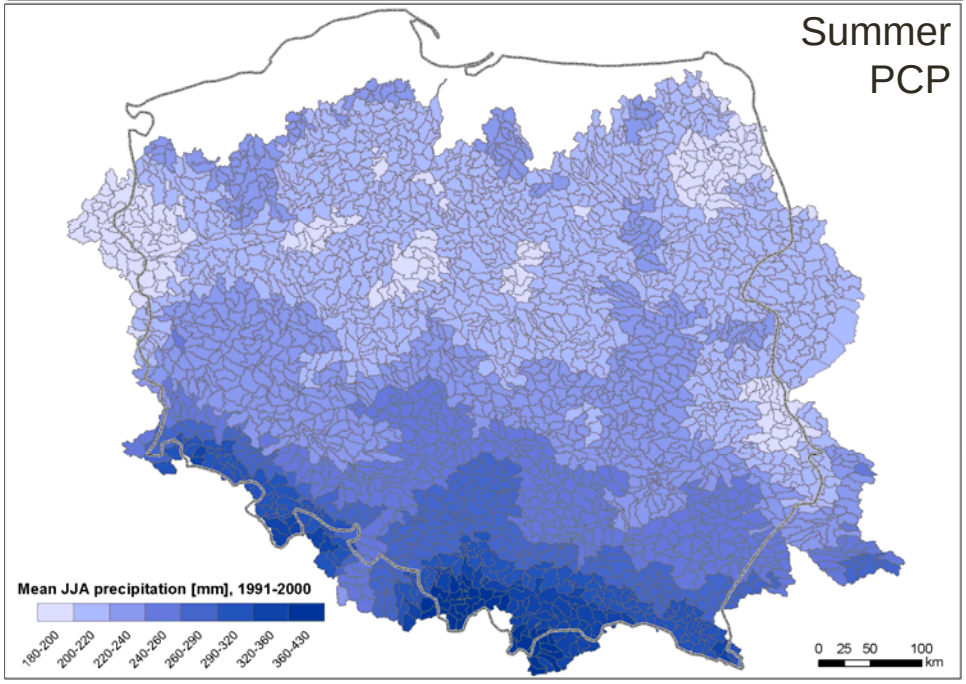
Mean annual precipitation at subbasin level

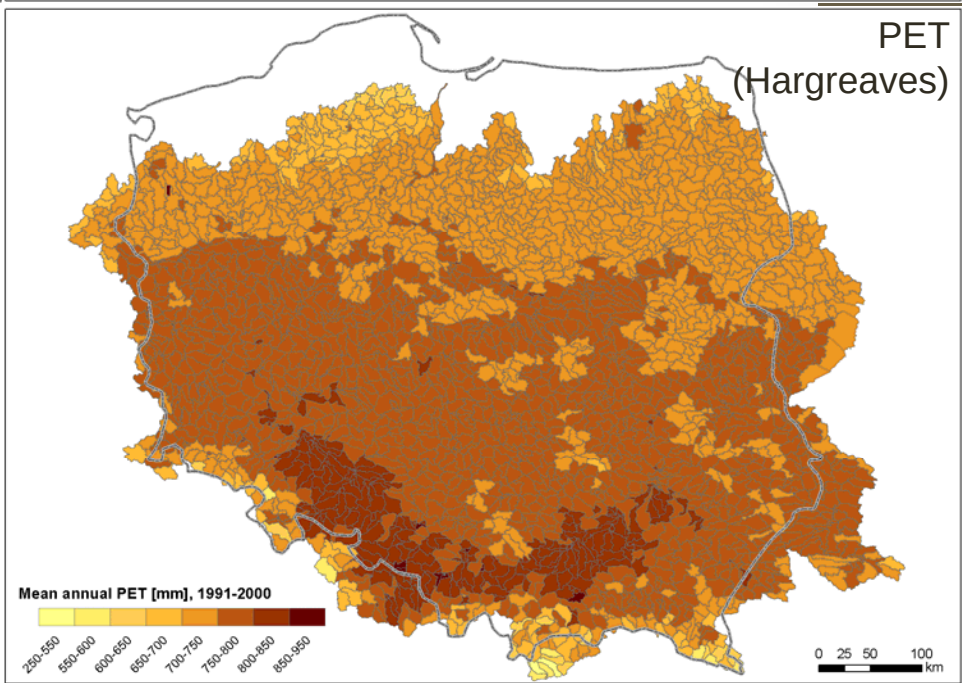


Model inputs/outputs – before calibration



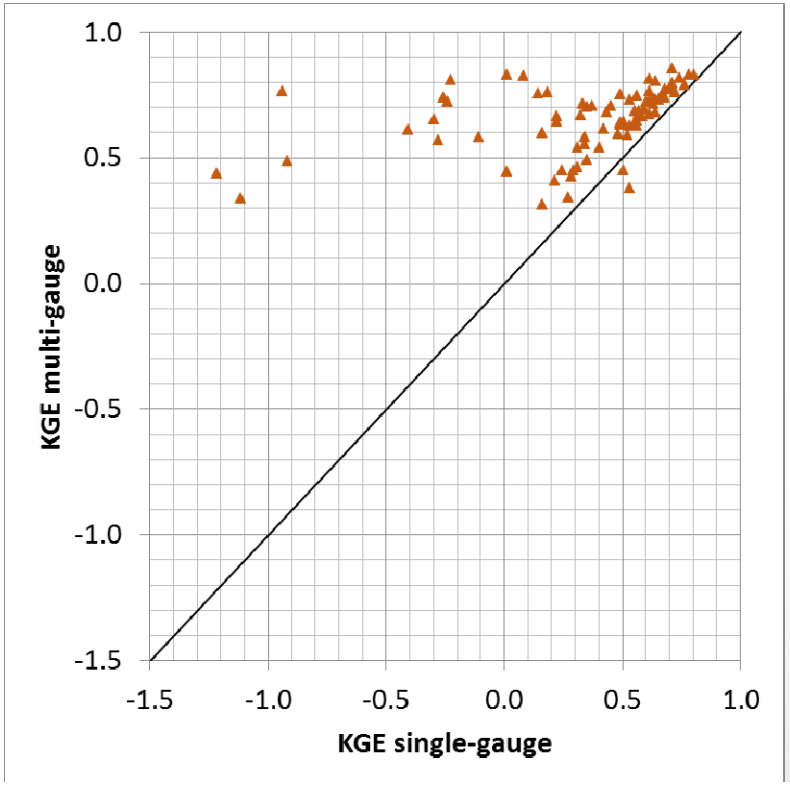






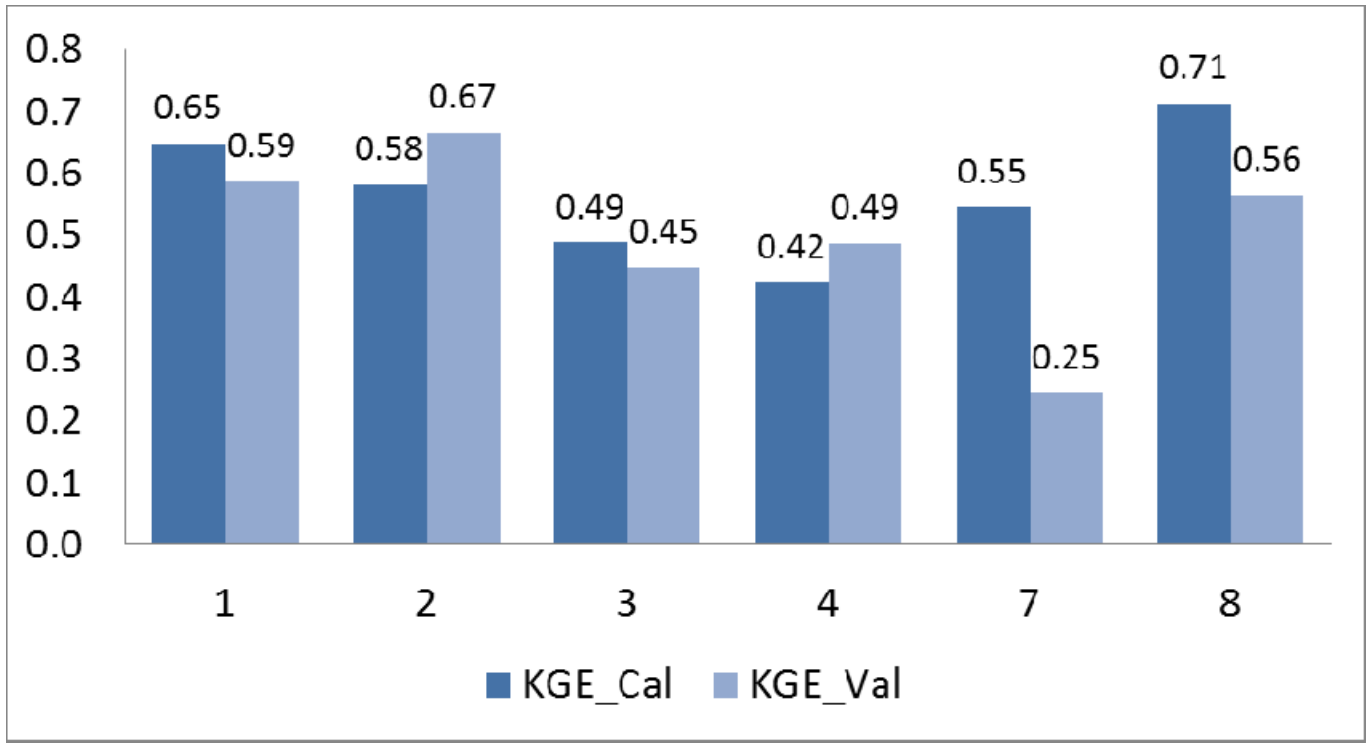
Initial results: single gauge vs multi-gauge

- What is the objective function value at 80 „benchmark“ catchments when the model is calibrated at the watershed outlets?
- Compare these values with the situation when the model is calibrated independently for every „benchmark“ catchments
- One SUFI-2 run
- KGE (Kling-Gupta Efficiency) used as an OF



Initial results: objective function (clusters)

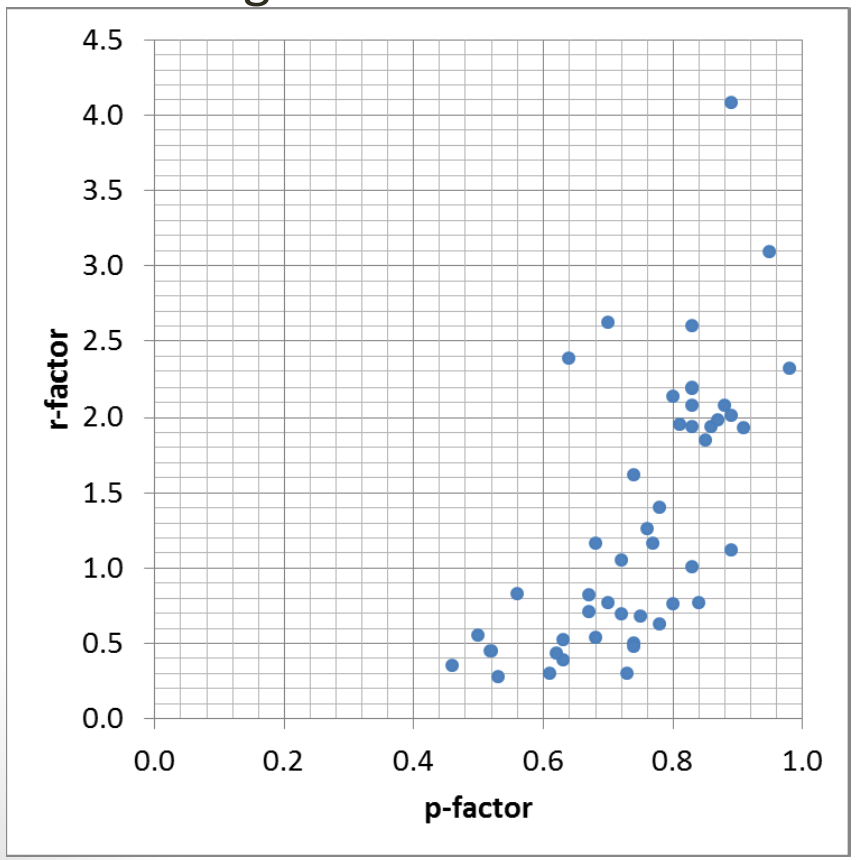
- KGE after the first SUFI-2 iteration for 6 out of 8 clusters (mean values across clusters)



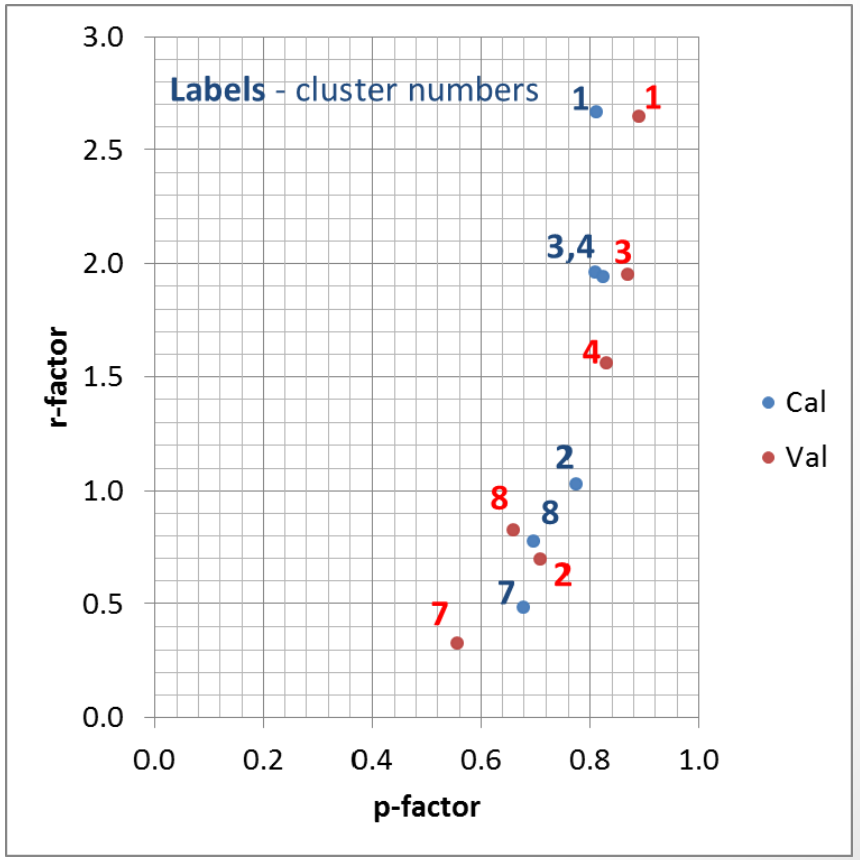
Initial results: 95PPU uncertainty measures

- p- and r-factors after the first SUFI-2 iteration for 6 out of 8 clusters

Gauge values



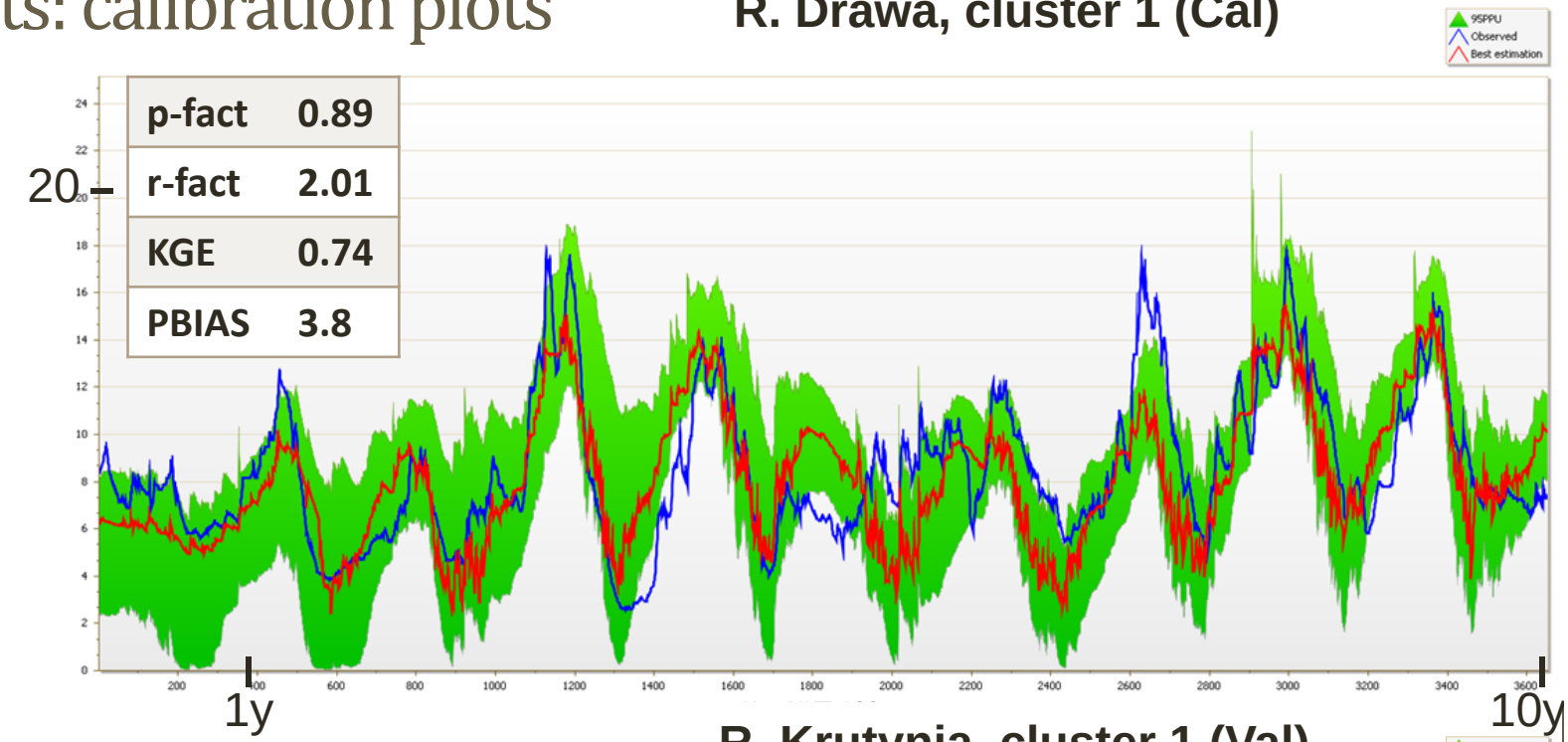
Mean cluster values



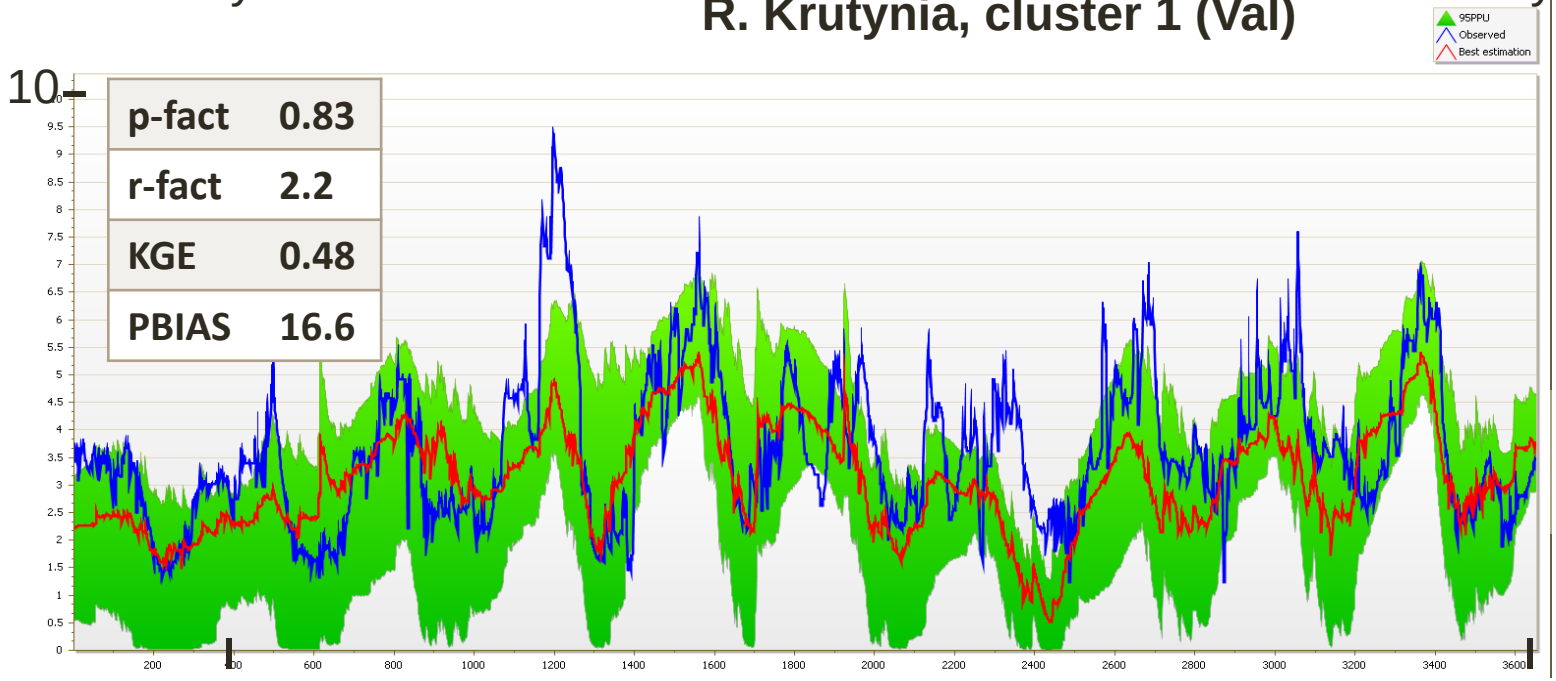
Initial results: calibration plots

Plots for the first SUFI-2 iteration

R. Drawa, cluster 1 (Cal)



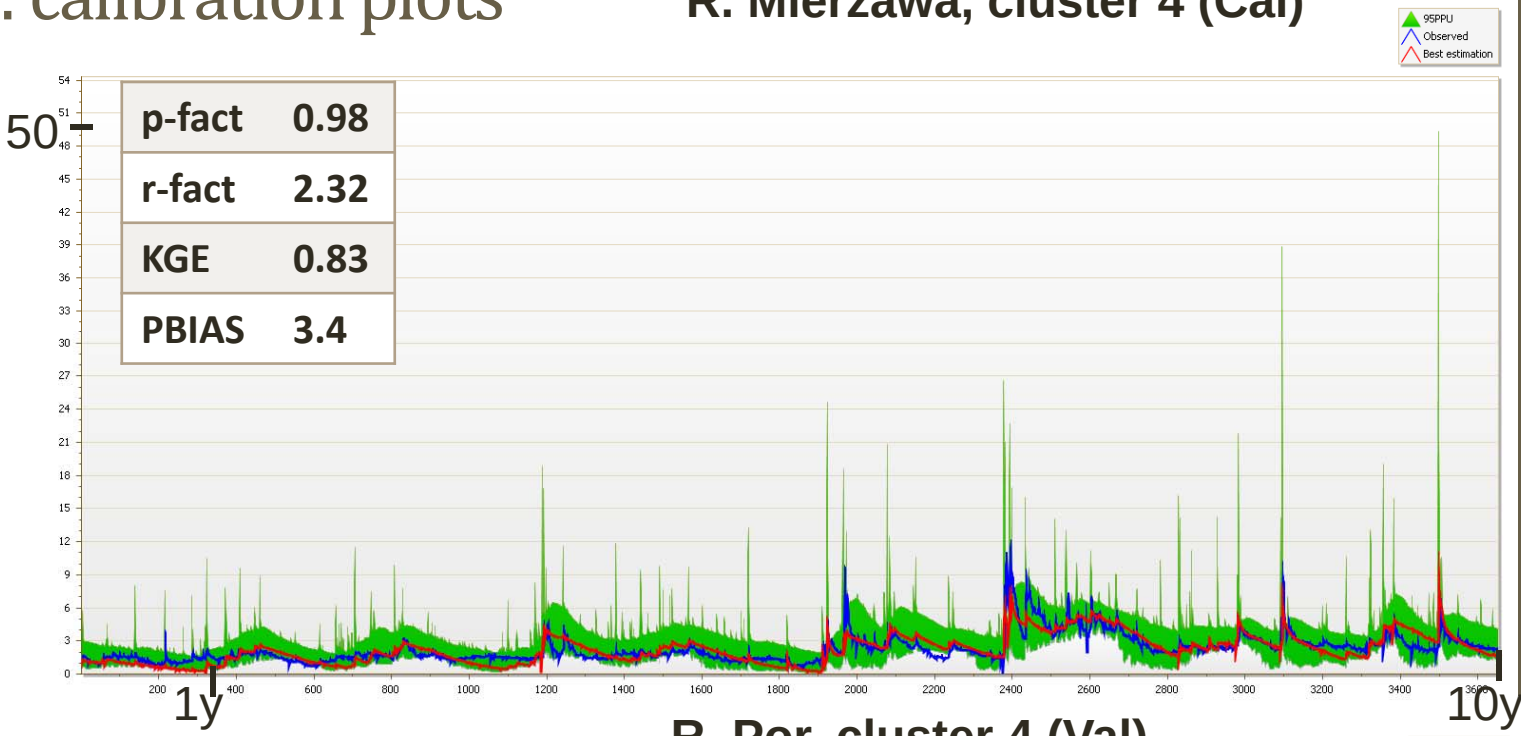
R. Krutynia, cluster 1 (Val)



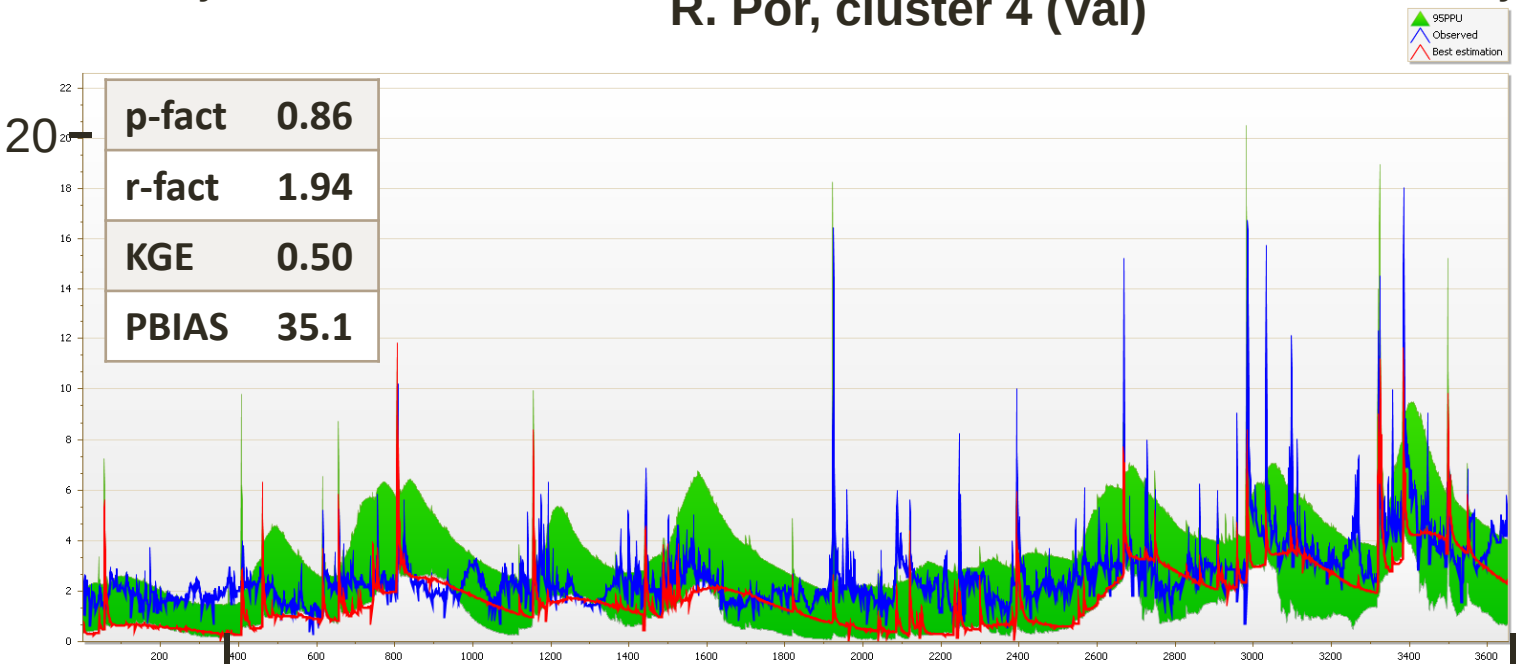
Initial results: calibration plots

Plots for the first SUFI-2 iteration

R. Mierzawa, cluster 4 (Cal)



R. Por, cluster 4 (Val)



Summary

- A framework for spatial calibration of large-scale SWAT models has been presented. It can be applied elsewhere provided that a sufficient number of gauged “benchmark” catchments exists
- Preliminary calibration results are “quite promising”
- The SWAT model of the Vistula and Odra basins will deliver “natural” daily flows simulated for the period 1951-2013
- Projections simulated using this model will enable disentangling pure climate change effects from other effects not related to climate
- In the nearby future projections of future streamflow (along with other projections) will be made available through an Interactive Web Mapping System (http://climateimpact.sggw.pl - under construction)

Acknowledgements

POLISH-NORWEGIAN RESEARCH PROGRAMME

CHASE-PL
Climate change impact assessment for selected sectors in Poland

Unterstützt von / Supported by

Alexander von Humboldt Stiftung/Foundation

FNP
Fundacja na rzecz Nauki Polskiej

Thank you!