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Analysis of long term baseflow changes in the Vistula catchment

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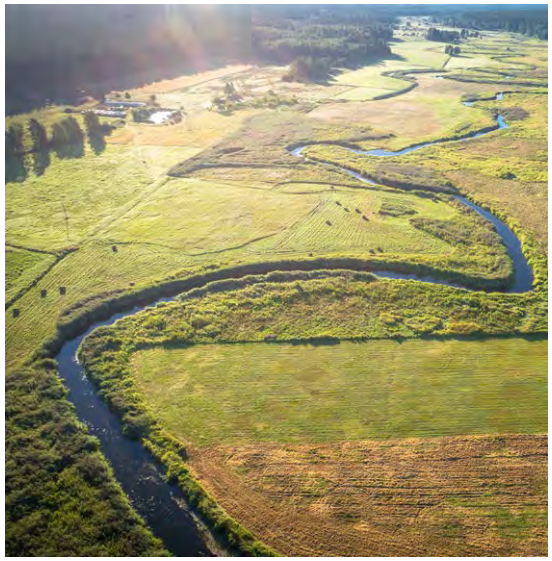
Introduction

- Baseflow is a portion of streamflow that is not directly generated from the excess rainfall during a storm event. Estimation of baseflow and direct runoff is useful to understand the catchment hydrology, including interaction of surface and sub-surface water, role of urbanization on runoff generation and the health of aquatic habitat within a stream.
- **Baseflow is the most important component of river flow in Poland**
- Proper quantitative assessment of baseflow is important for conducting efficient water management.
- The magnitude of baseflow and its part in the total river flow is a function of climate, land cover, hydrogeological conditions, river morphology and anthropogenic factors.



Motivation

- In Poland there is a lack of complementary studies on quantification of baseflow and its spatio-temporal variability
- BFI - proxy measure of groundwater

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Aim of the study

- Quantification of baseflow of the Vistula catchment in the long time horizon (1951-2020);
- Determination of the baseflow index (BFI);
- Analysis of changes in baseflow in time;
- Analysis of trends in baseflow.

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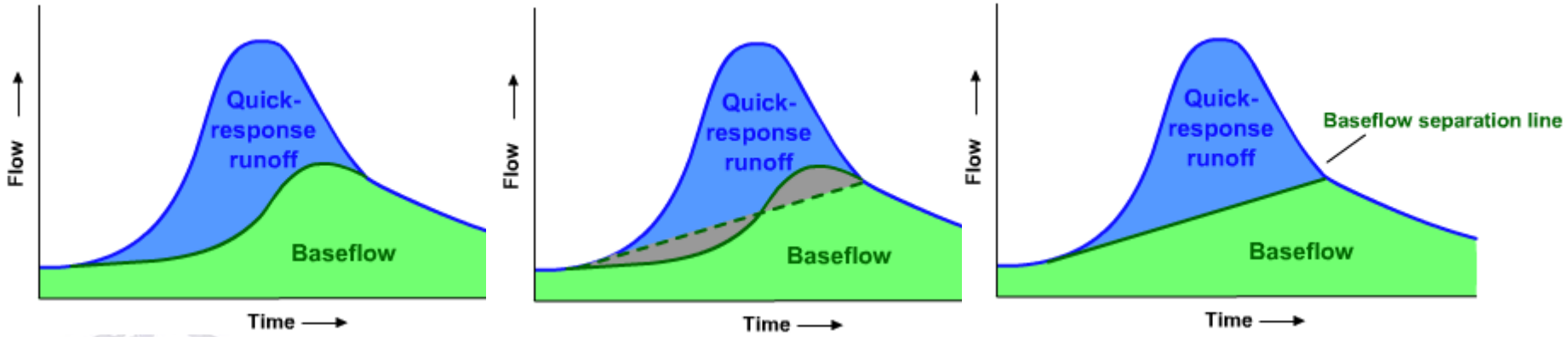
Baseflow analysis



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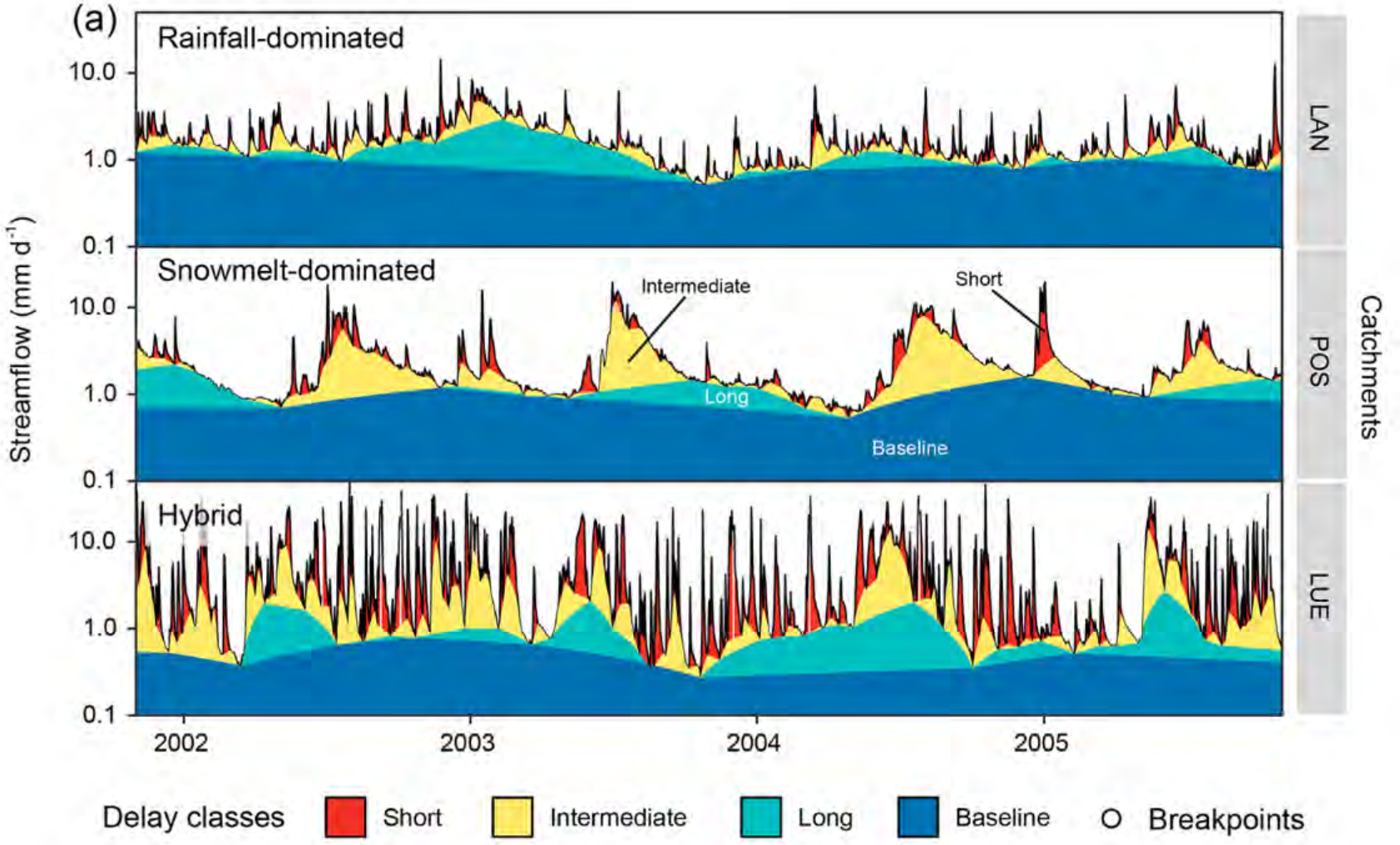
Baseflow analysis



Stoelzle et al. 2020 HESS

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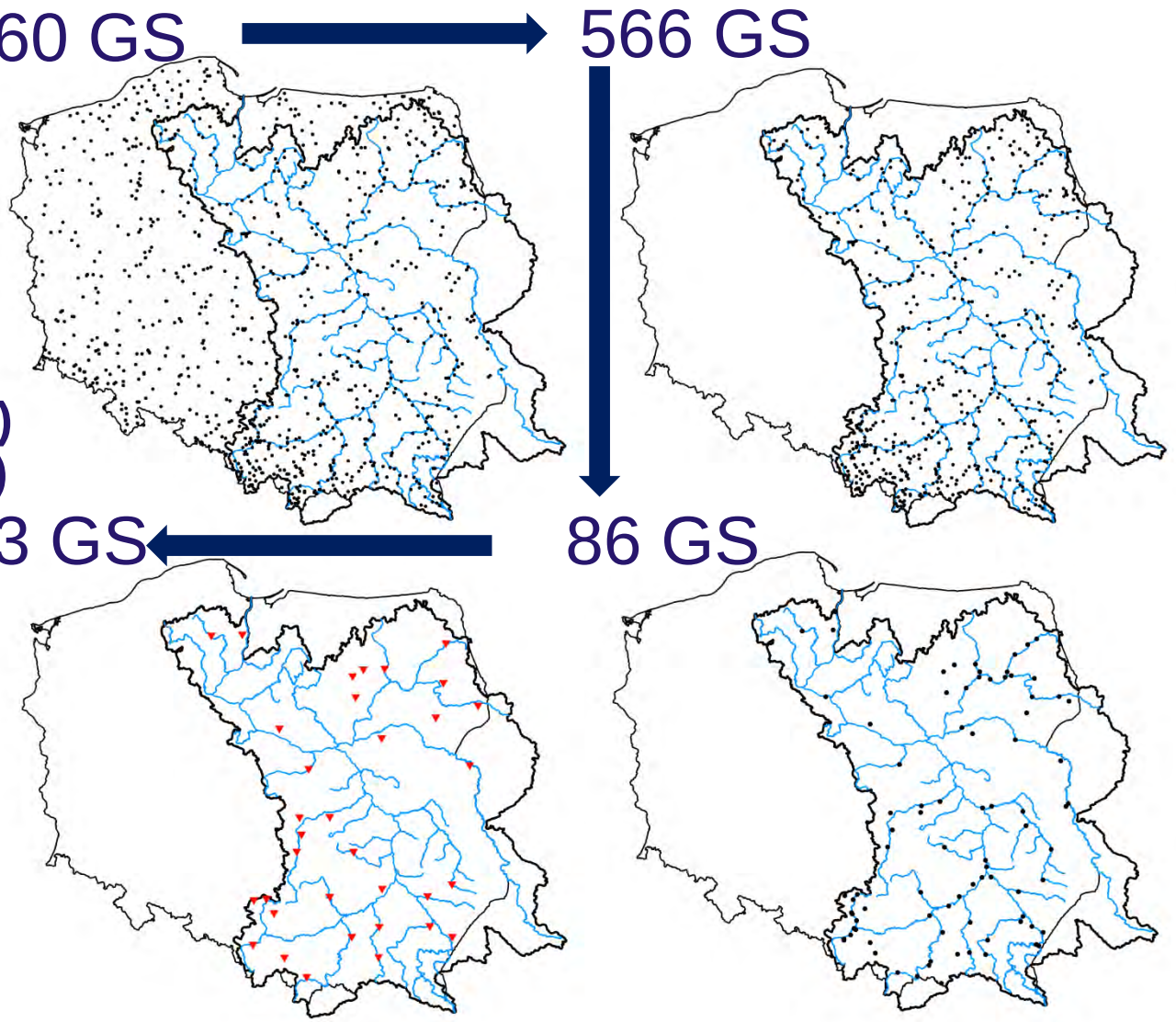
Materials and methods – data acquistion and gauging station selection

GS - gauging station

Gauging station selection criteria:

- **maximum longest daily flow data (86 GS) – 70 years (1951-2020)**
- **data without gaps**
- **not infuenced by any dams (33 GS)**



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Materials and methods – baseflow index calculation

- Recession Analysis Methods

Method	Storage-discharge relationship	Recession curve equation
Maillet (1905)	$S = Q/\alpha$	$Q_t = Q_0 e^{-\alpha t}$
Boussinesq (1905)	$S = \int f(Q)dt$	$Q_t = Q_0(1 + n\,t)^{-2}$
Coutagne (1978)	$\frac{dQ}{dt} = -aQ^b$	$Q_t = [Q_0^{1-b} - (1-b)at]^{1/1-b}$
Wittenberg (1999)	$S = cQ^d$	$Q_t = Q_0\left[1 + \frac{(1-d)Q_0^{1-d}}{cd}t\right]^{1/d-1}$

- Recession Extraction Methods

Method	Criterion	Minimum duration (days)*	Filter criterion (removed days)*	Exclusion of anomalous recession decline*
Vogel and Kroll (1992)	Decreasing 3-d moving average	10	First 30%	$\frac{Q_i - Q_{i+1}}{Q_{i+1}} > 30\%$
Brutsaert and Nieber (1977)	$dQ/dt < 0$	6–7	First 3–4, last 2	$\frac{dQ_{t+1}}{dt} > \frac{dQ_t}{dt}$
Aksoy and Wittenberg (2011)	$dQ/dt < 0$	5	First 2	$CV > 0.20$

- Parameter estimation technique
  - Least squares
  - Linear regression
  - Lower envelope
  - Data Binning

- 20 combinations
- **20 baseflow** for each station

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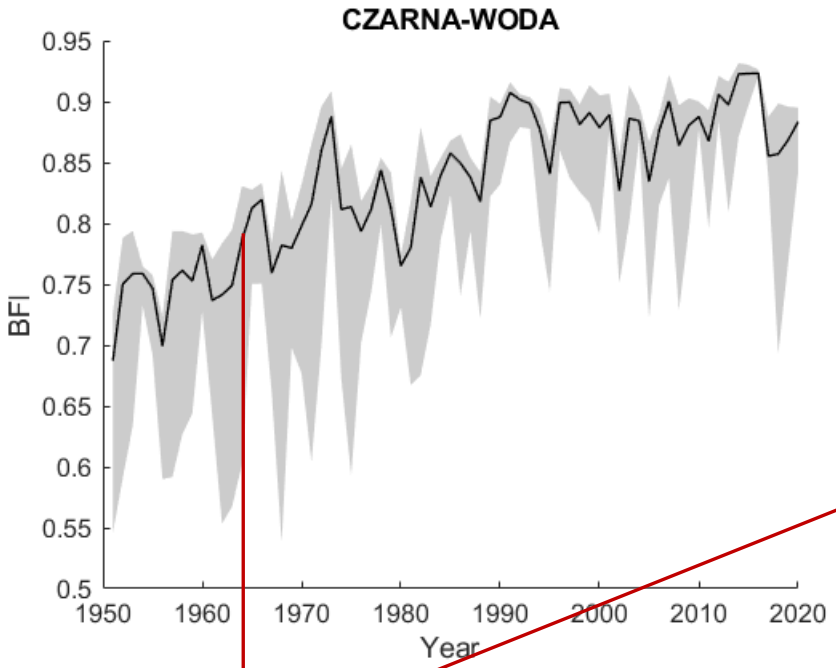
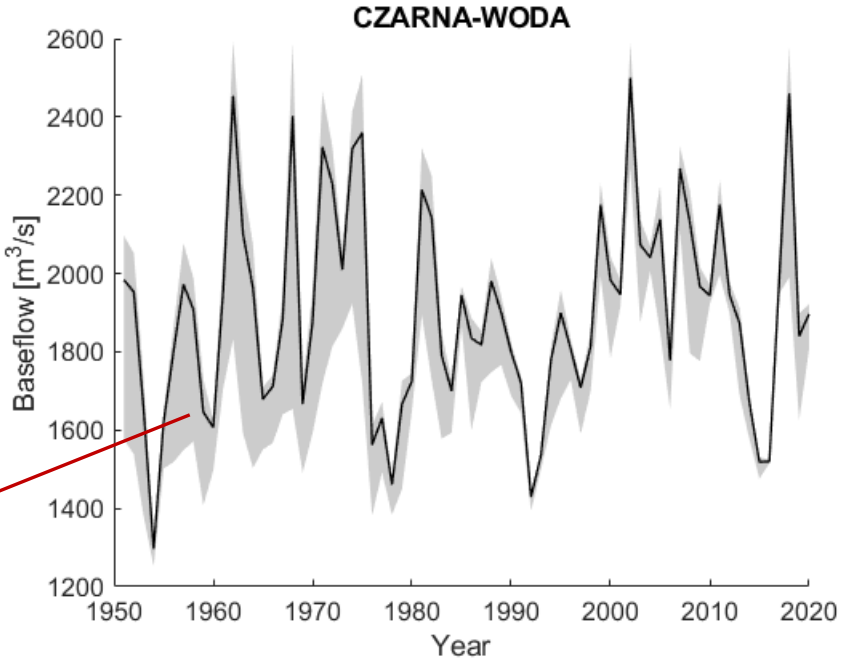
Materials and methods – trend analysis





- Avarage baseflow (BFI) of 20 combinations (black line)
- Shaded area indicates the range of variation for the 20 considered combinations

- Trend analysi was performed for avarage BFI of 20 considered combinations

Modified Mann Kendall test

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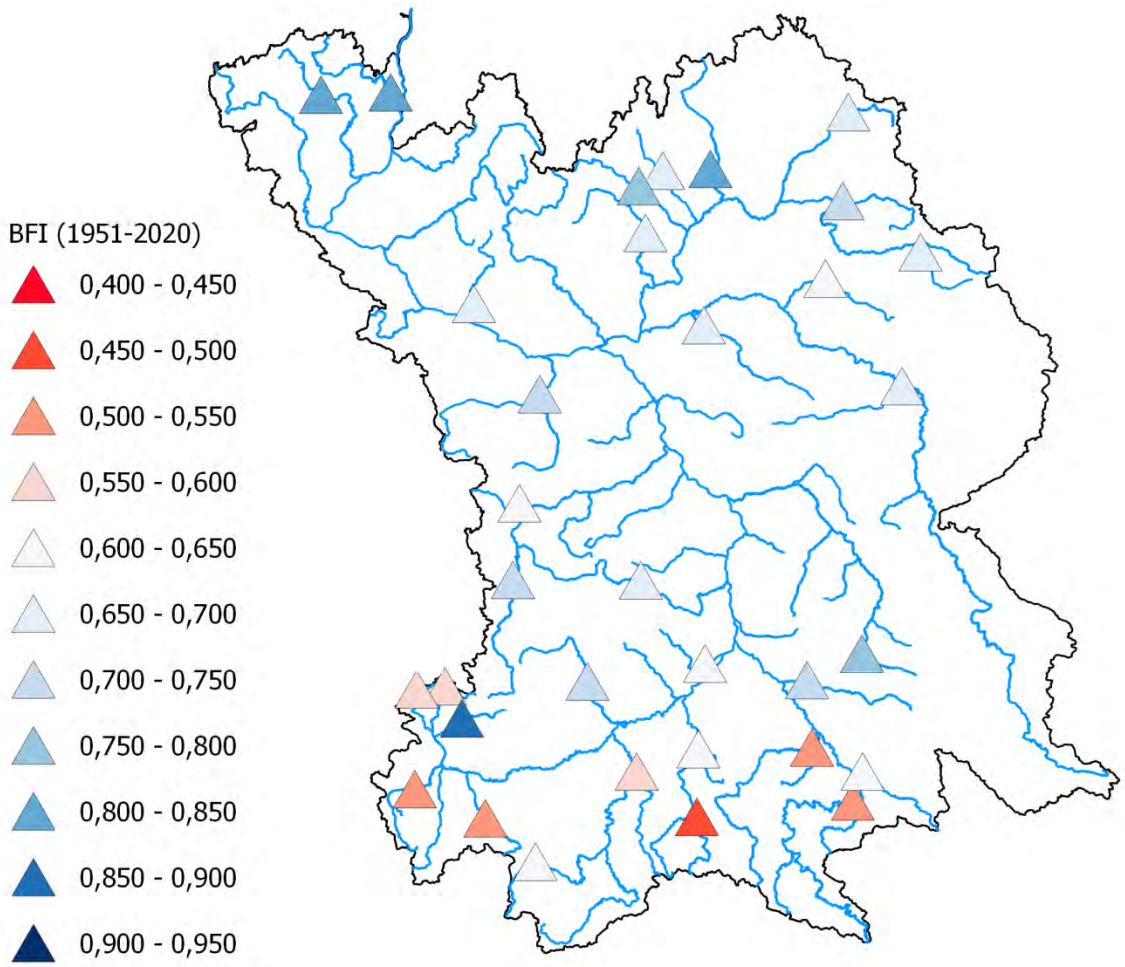
Results –BFI quantification

- Baseflow index
  - $BFI = \frac{Baseflow}{Total\ flow}$

- **Baseflow index**
- $\boldsymbol{meanBFI_{Vistula} = 0.67}$
- $\boldsymbol{min\ BFI_{Vistula} = 0.48}$
- $\boldsymbol{maxBFI_{Vistula} = 0.89}$



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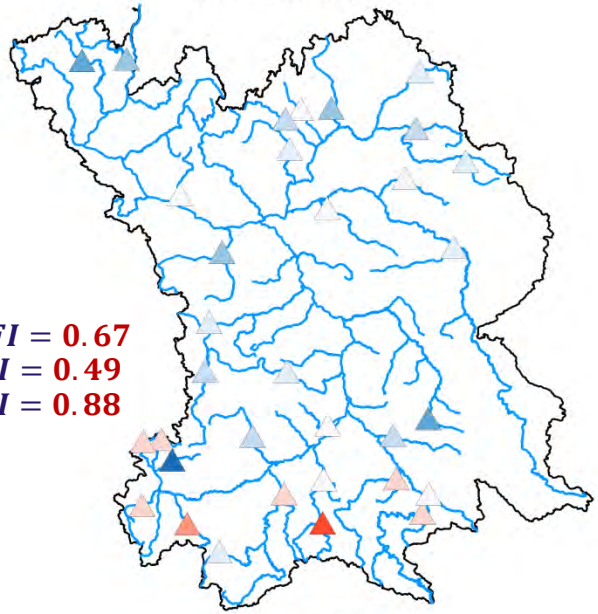
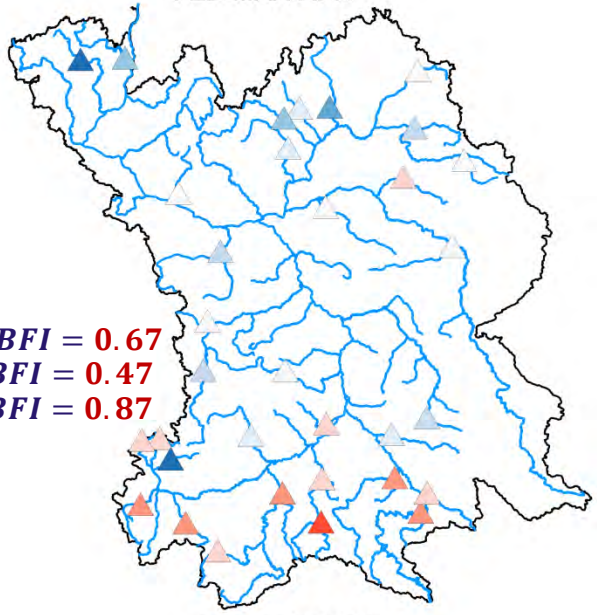
NOV-DEC-JAN



$meanBFI = 0.67$
$min\ BFI = 0.49$
$maxBFI = 0.88$

FEB-MAR-APR

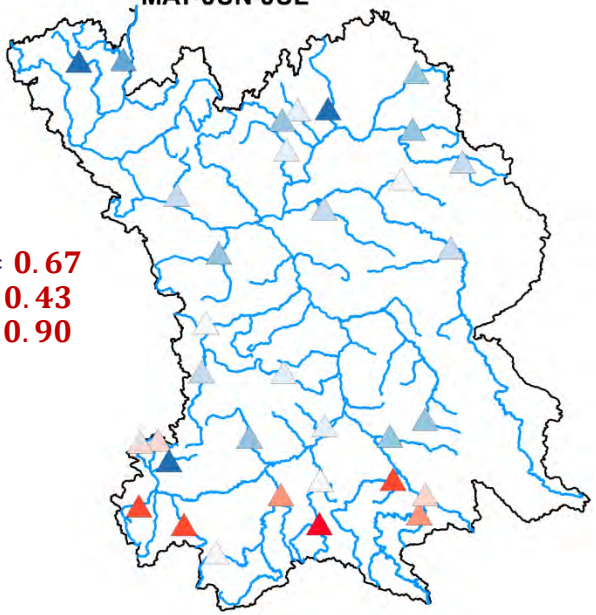


$meanBFI = 0.67$
$min\ BFI = 0.47$
$maxBFI = 0.87$

BFI (1951-2020)

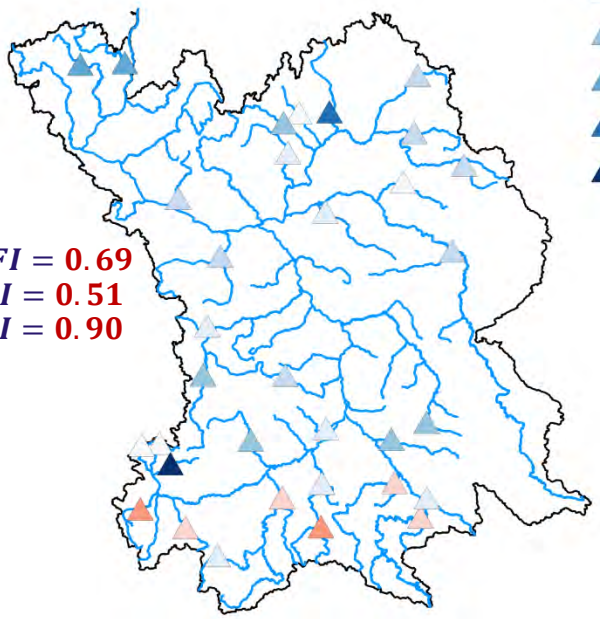
- 0,400 - 0,450
- 0,450 - 0,500
- 0,500 - 0,550
- 0,550 - 0,600
- 0,600 - 0,650
- 0,650 - 0,700
- 0,700 - 0,750
- 0,750 - 0,800
- 0,800 - 0,850
- 0,850 - 0,900
- 0,900 - 0,950

MAY-JUN-JUL



$meanBFI = 0.67$
$min\ BFI = 0.43$
$maxBFI = 0.90$

AUG-SEP-OCT



$meanBFI = 0.69$
$min\ BFI = 0.51$
$maxBFI = 0.90$

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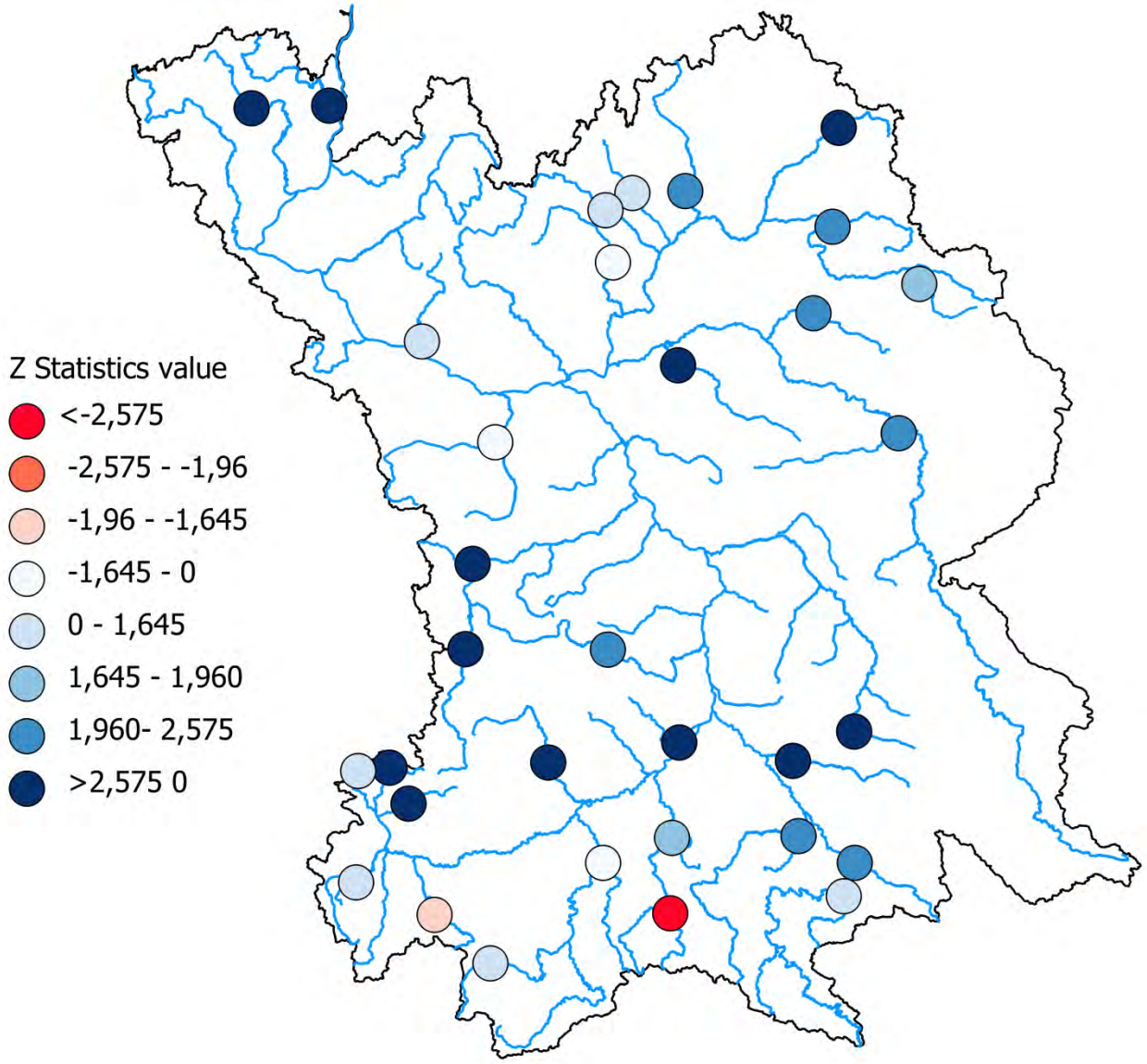
Results – trend analysis

- 28 GS – BFI increasing
  - 19 GS - statistically significant
- 5 GS - BFI decreasing
  - 1 GS - statistically significant



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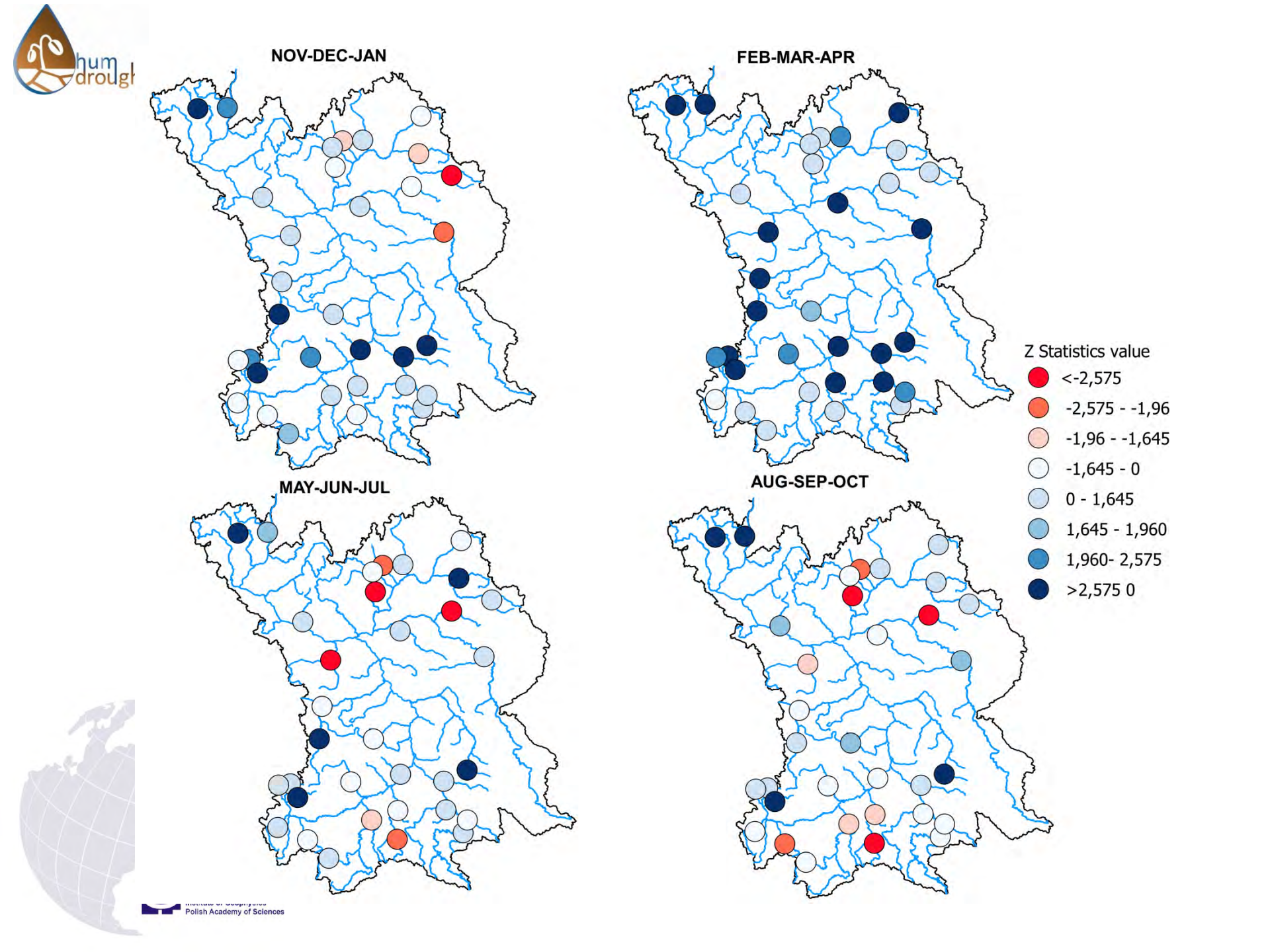
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MAY-JUN-JUL
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Z Statistics value
<-2,575
-2,575 - -1,96
-1,96 - -1,645
-1,645 - 0
0 - 1,645
1,645 - 1,960
1,960- 2,575
>2,575 0

Conclusions

- Baseflow component in the Vistula catchment is increasing
- The average share of the baseflow component of river flow in the Vistula catchment is 0.67
- For 20 (out of 33) analysed gauging stations, statistically significant trends of changes in BFI were found
- It seems that the causes of changes in baseflow should be sought in cumulative interactions of anthropopression and climate.