Effect of Climate Change on Environmental Flow Indicators in the Narew Basin, Poland

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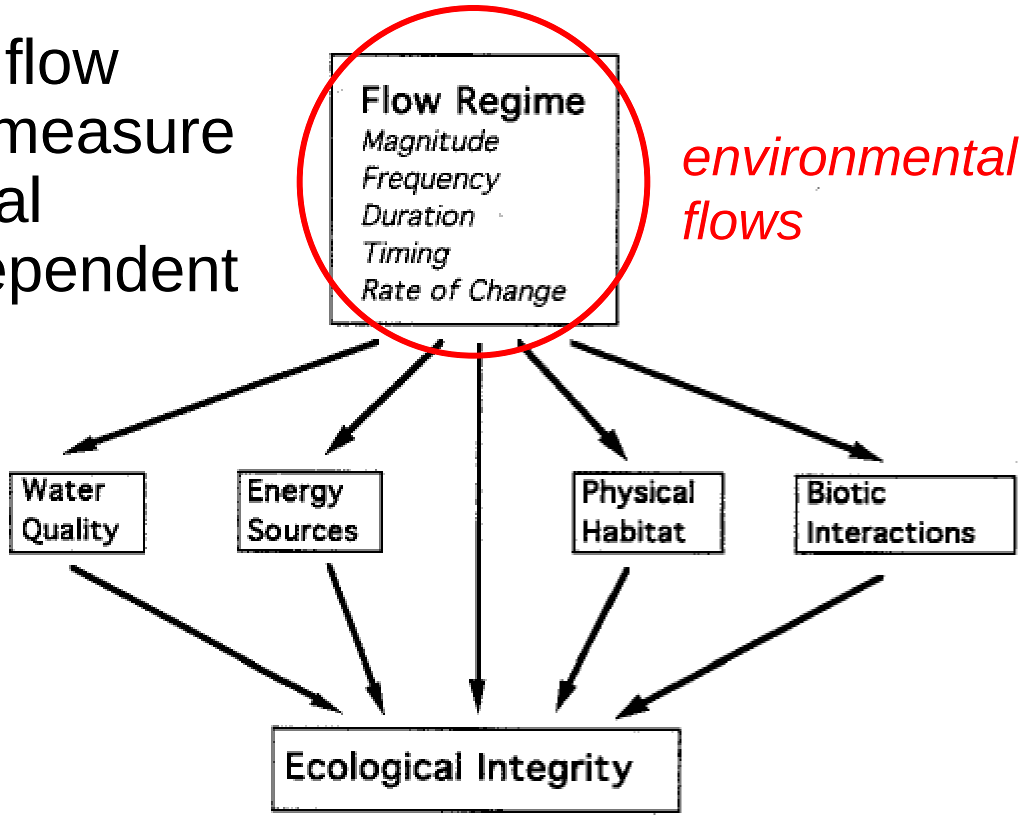
Outline

- Introduction: Background, motivation
- Tools and methods
  - Hydrological models
  - Climate change scenarios
  - Approach of environmental flow indicators assessment
- Results
- Conclusions & Outlook

The Natural Flow Paradigm

- Poff *et al.* 1997 *Bioscience*
- Streamflow – a master variable
- Maintaining natural flow variability as a key measure of keeping ecological integrity of water-dependent ecosystems

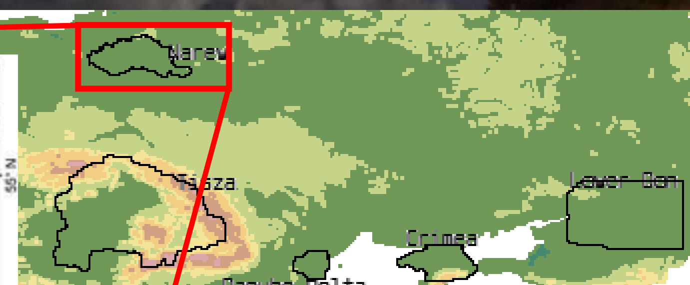


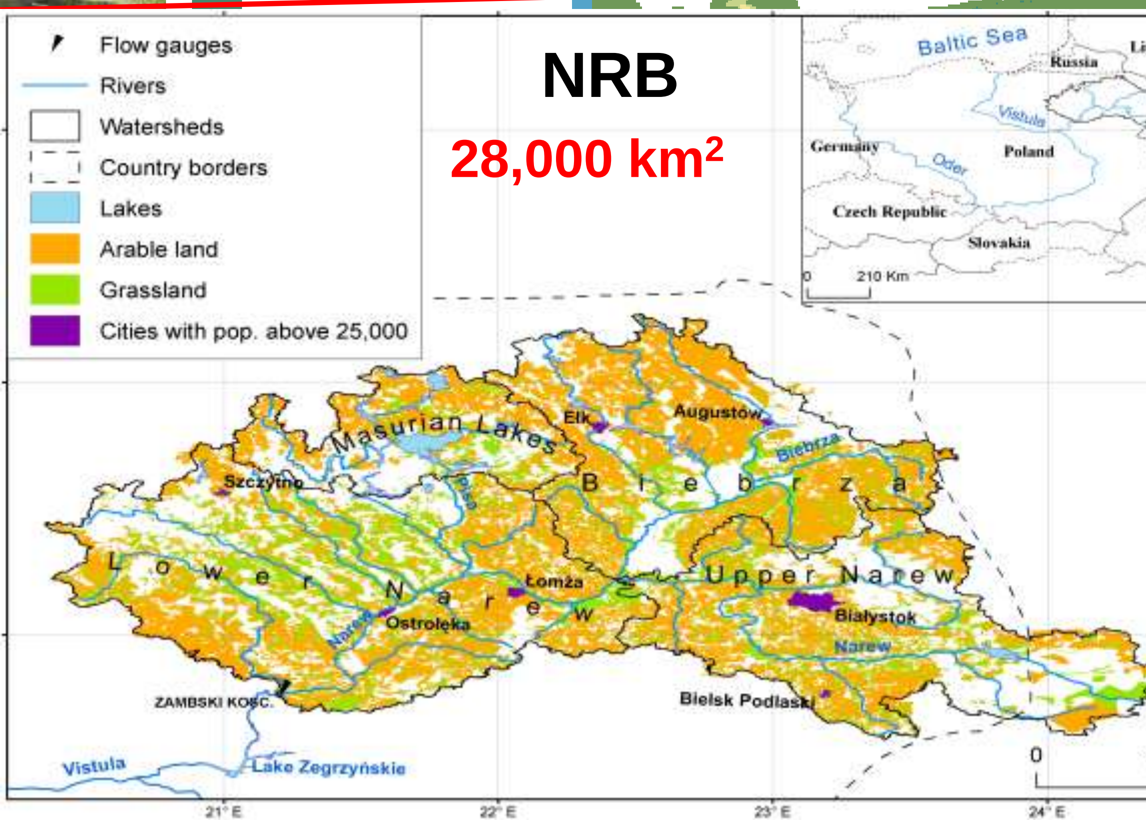
Poff *et al*. 1997

Background – SCENES project

- EU-FP6 IP SCENES „Water Scenarios for Europe and for Neighbouring States”
- Nov 2006 – Apr 2011
- 23 partners from 17 countries
- Similar methodology applied at three levels: pan-European, regional and local (pilot areas)
- Water for Nature indicators - impacts of climate change and socio-economic scenarios

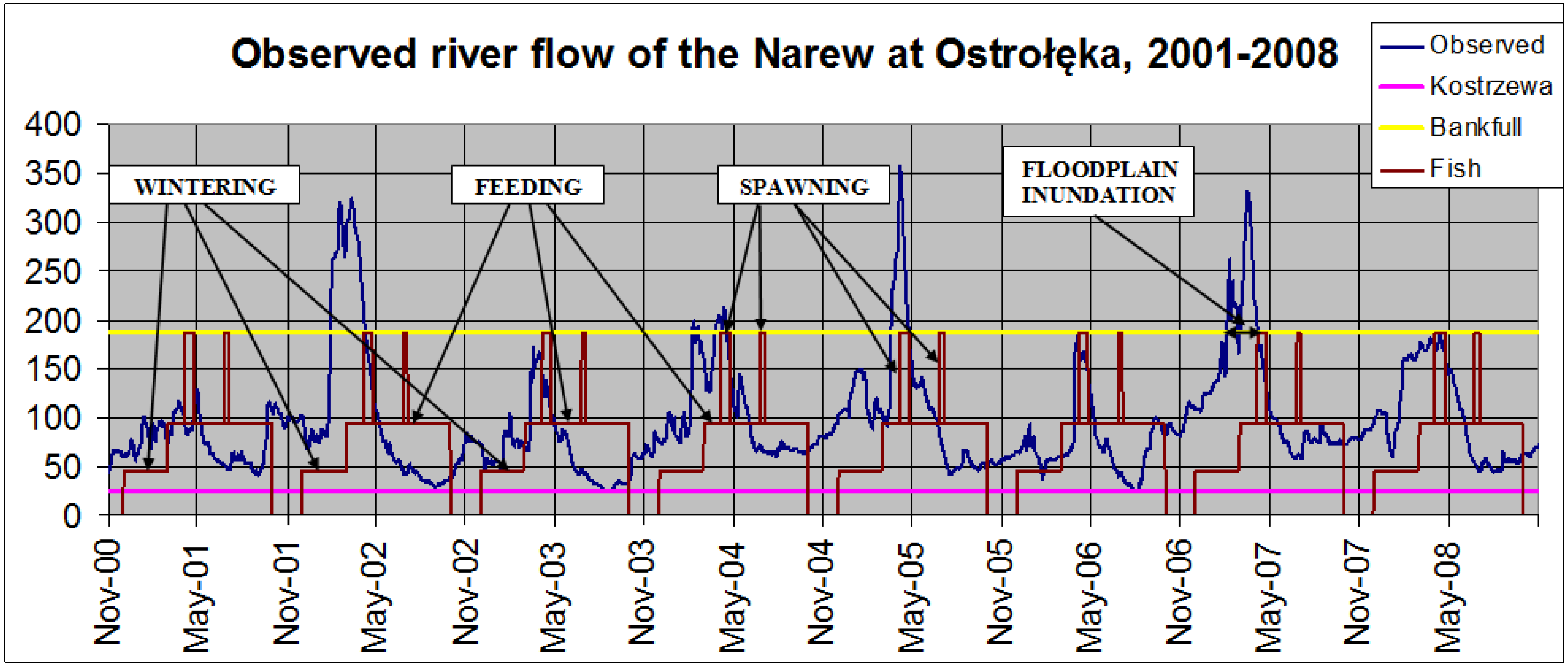
- Narew Rive


Narew
Tisza
Lower Don
Crimea
Danube Delta


Flow gauges
Rivers
Watersheds
Country borders
Lakes
Arable land
Grassland
Cities with pop. above 25,000
NRB
28,000 km²
Baltic Sea
Russia
Lithuania
Byelarus
Vistula
Germany
Oder
Poland
Czech Republic
Slovakia
Ukraine
210 Km
Masurian Lakes
Ełk
Augustów
Biebrza
Szczytno
Lower Narew
Upper Narew
Łomża
Ostrołęka
Białystok
Narew
Bielsk Podlaski
ZAMBSKI KOŚC.
Vistula
Lake Zegrzyńskie
21° E
22° E
23° E
24° E

E-flows in the Narew context

- Adapted Building Block approach (Tharme & King 1997)
- Requirements of fish (pike & wels catfish) and floodplain vegetation (reed bed & sedge communities)



Piniewski *et al*. 2011 Pol. J. Environ. Stud.

Objective

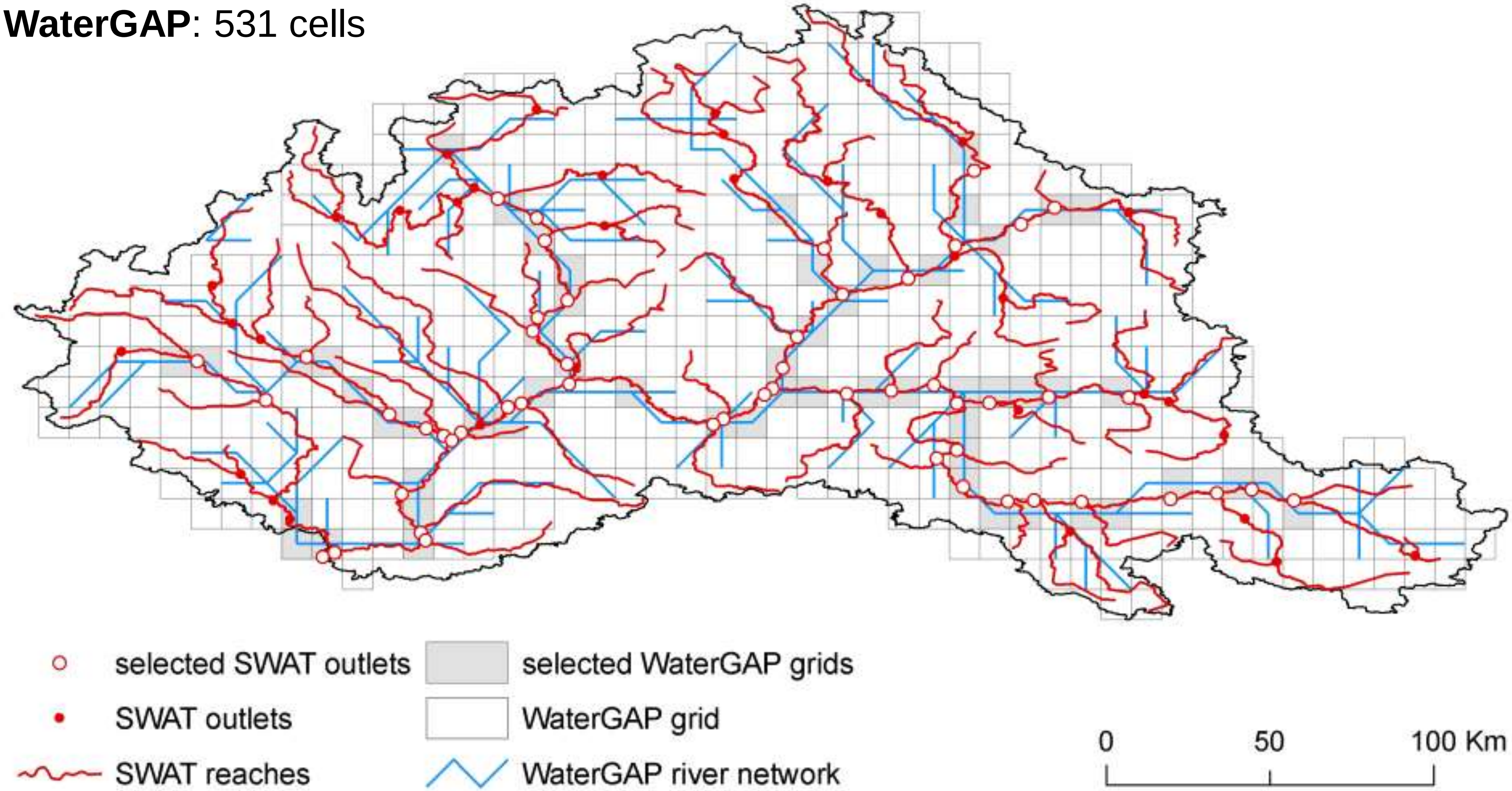
- To analyse the effect of climate change on environmental flow indicators in a semi-natural river basin using two different types of distributed models
  - ➢ Global model – WaterGAP (CESR Kassel)
  - ➢ Watershed model – SWAT
- CC impact: SRES-A2 GCMs: IPSL-CM4 & MIROC3.2 for 2050s
- Environmental flow indicators – IHA (Indicators of Hydrologic Alteration) approach

Modelling approaches

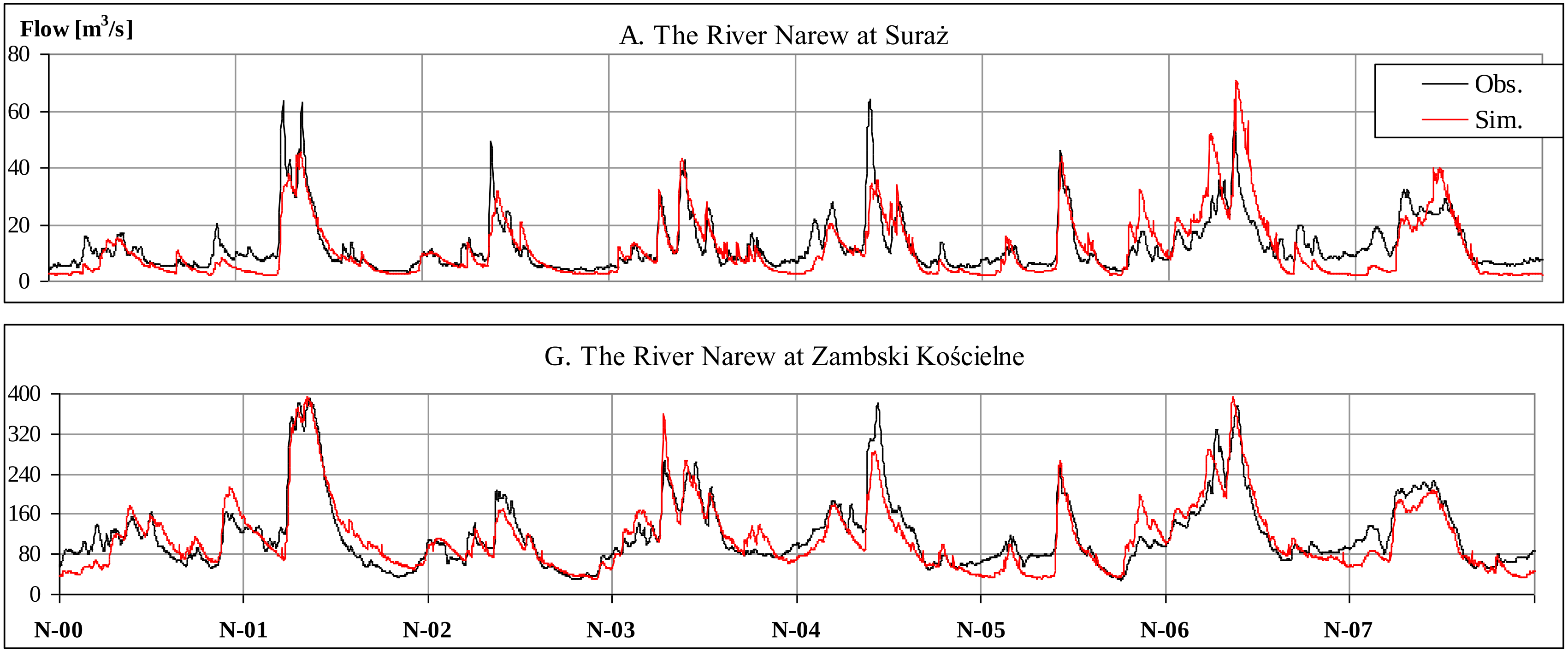
Aspect	SWAT	WaterGAP
Basic unit	Hydrologic Response Unit	5' by 5' grid cell
Potential ET	Penman-Monteith	Priestley-Taylor
Actual ET	Evaporation from canopy & soil + sublimation + plant water uptake	Evaporation from canopy & vegetated soil + sublimation
Snowmelt	Degree-day method	
Surface runoff	Modified SCS curve number method	HBV method
Redistribution in soil	Storage routing method between up to 10 soil layers	No redistribution, one soil layer
Soil water content	Variation between absolute zero and saturation	Variation between the wilting point and field capacity
Groundwater storage	Two groundwater storages (shallow unconfined and deep confined)	One groundwater storage
Baseflow	Recession constant method	Linear storage equation
Flood routing	Variable storage coefficient method	Linear storage equation

Modelling setup

SWAT: 151 sub-basins, 1131 HRUs
WaterGAP: 531 cells



SWAT – spatially distributed calibration

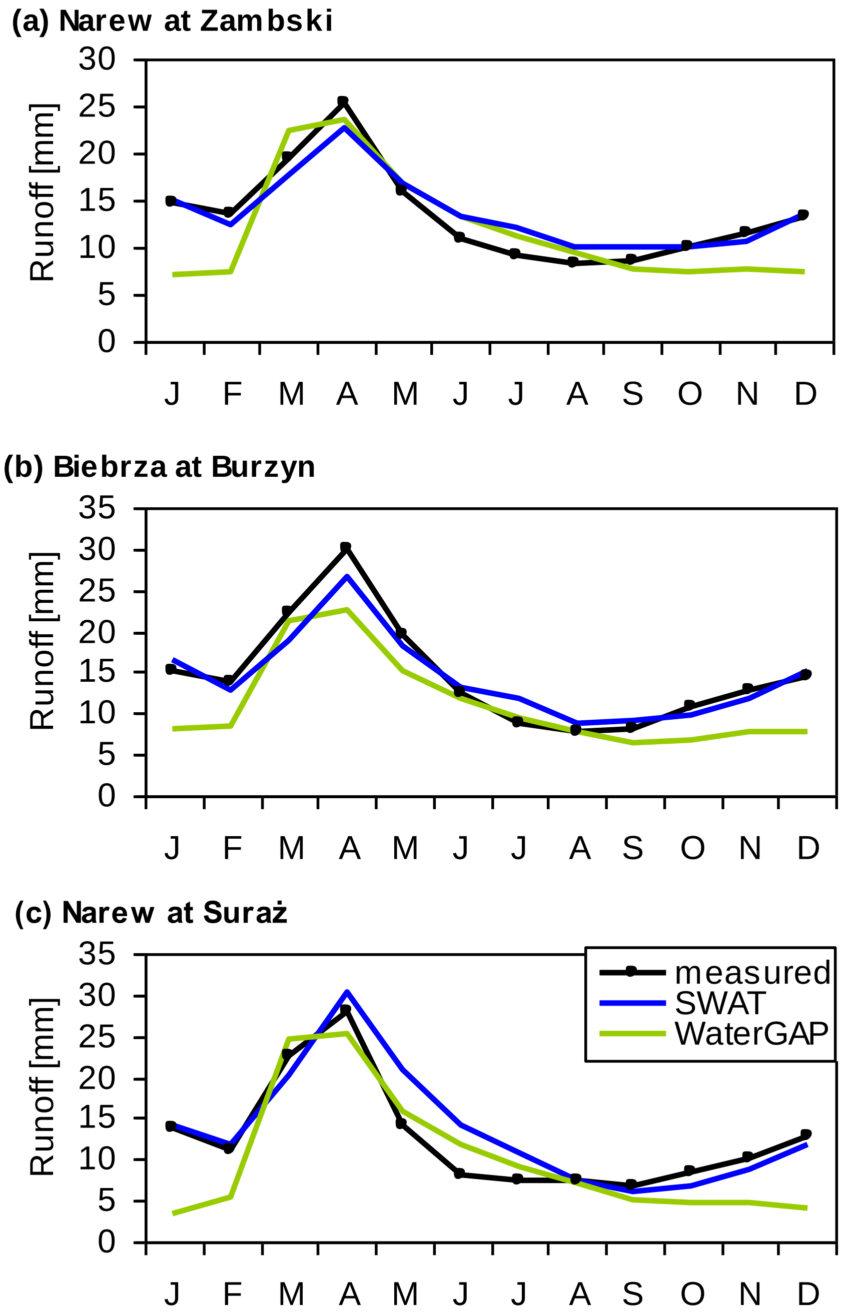


- Mean NSE for 11 calibration gauges:
  - Calibration period: 0.68
  - Validation period: 0.57

Piniewski & Okruszko 2011 Geoplanet: Earth and Planetary Sciences

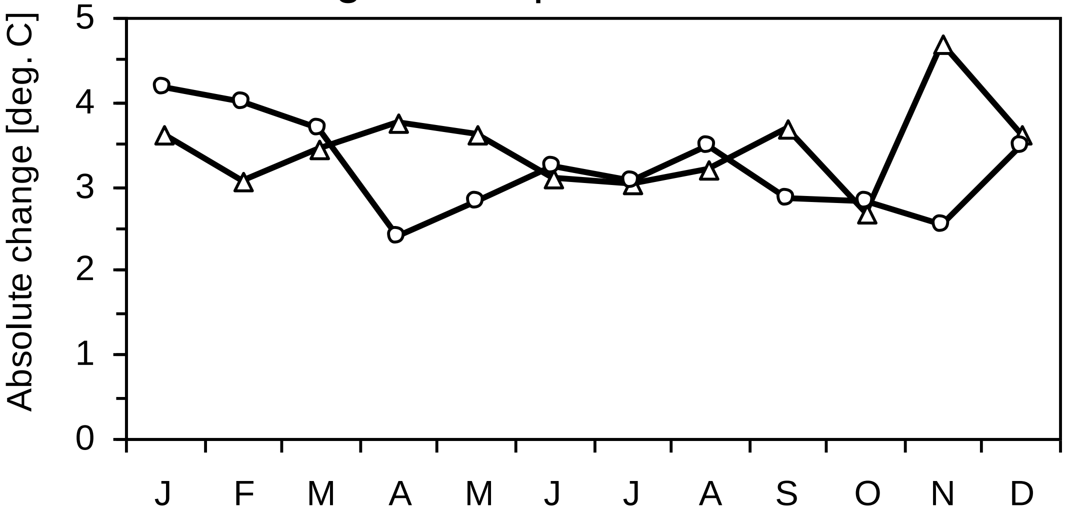
Baseline simulated & measured runoff

- Underestimation of mean runoff by 12-24% in WaterGAP
- Low runoff period lasts until Feb. in WaterGAP
- Overall – acceptable (WaterGAP calibrated for Europe not for Narew!)



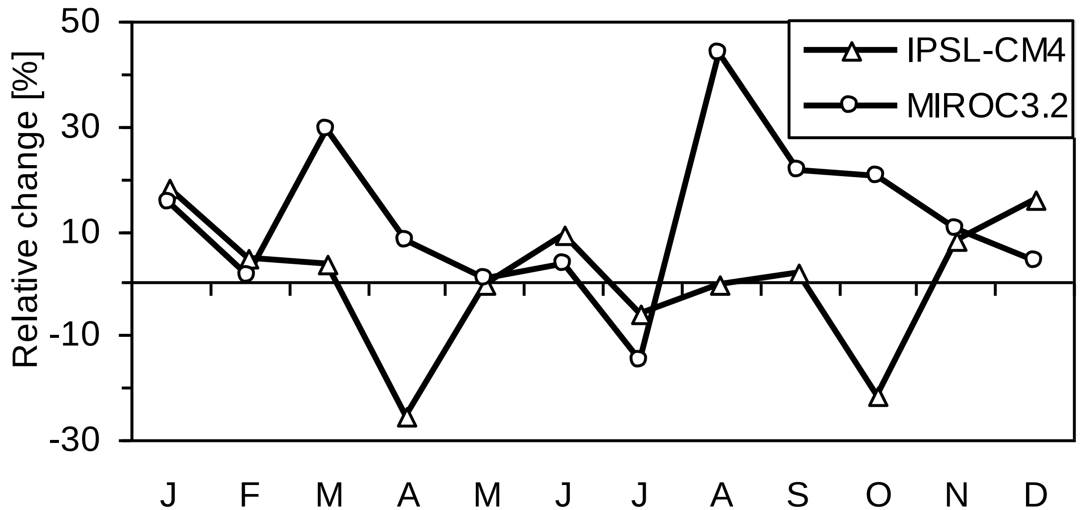
GCM projections for 2050s – basin average

(a) Change in temperature



Mean annual change:
IPSL-CM4: 3.5 ˚C
MIROC3.2: 3.2 ˚C

(b) Change in precipitation



Mean annual change:
IPSL-CM4: 1%
MIROC3.2: 11%

Indicators of Hydrological Alteration approach

- Desktop technique, cf. Richter *et al*. (1996, 1997)
- Comparison of natural & altered flow regime
- Calculation of 16 indicators (Richter statistics) representing the average and variability
- Threshold for difference in indicators (scenario vs. baseline) set to 30%
- Aggregation of differences into a colour-coding system
  - Number of different Richter stats:

0
1-5
6-10
11-16

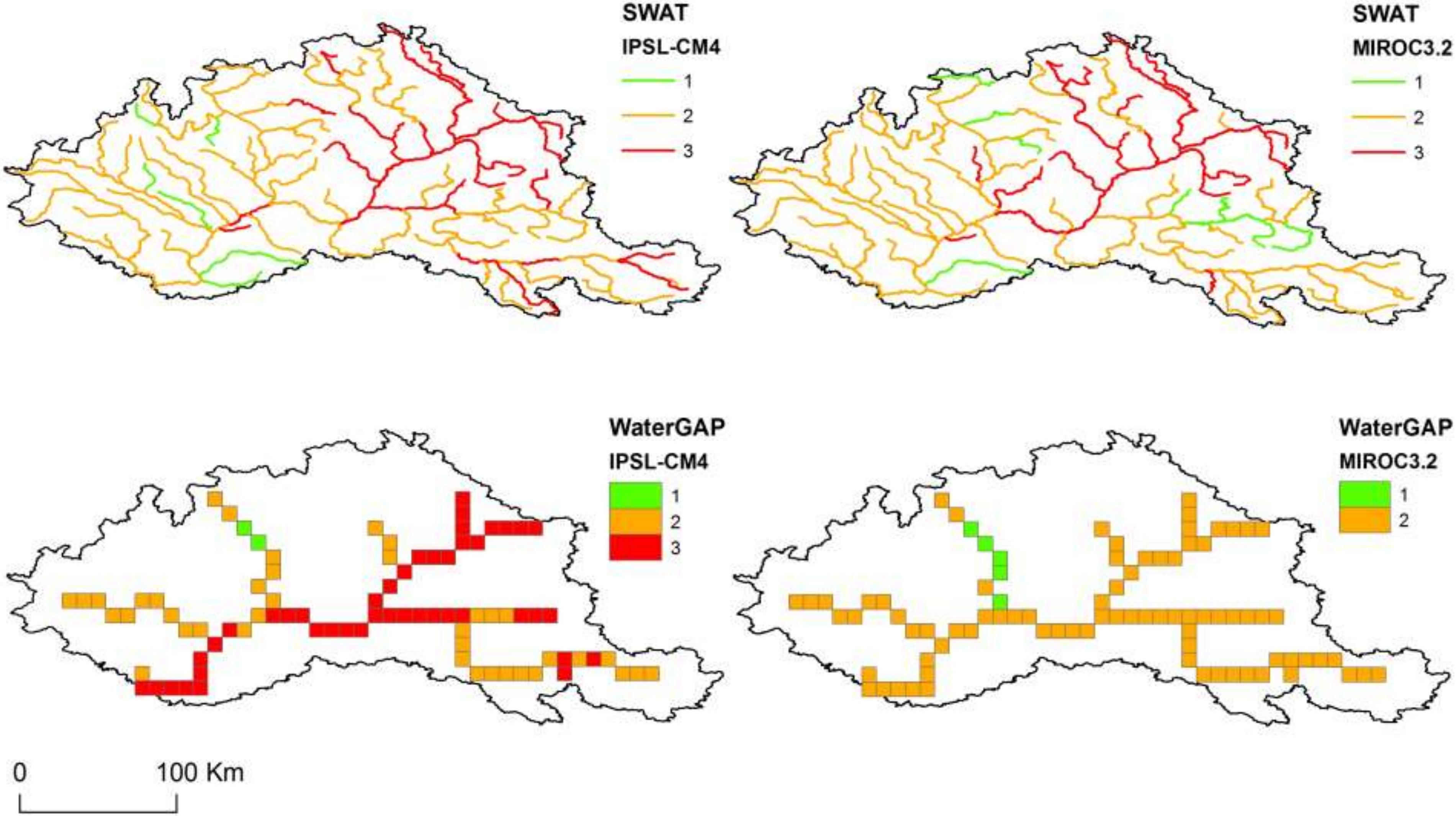
Environmental flow indicators (Richter statistics)

Regime characteristic	*Parameter monthly (one value per year)*	*Indicator (one value per record)*
Flood Magnitude & Frequency	Number of times that monthly flow exceeds threshold (all-data naturalised Q5 from the baseline period)	Median (**P1**) 25th-75th percentile span (**P2**)
Flood Timing	Month (as number Jan=1, Dec=12) of maximum flow	Mode of month (**P3**)
Seasonal Flow	January flow (mm runoff)	Median (**P4**) 25th-75th percentile span (**P5**)
	April flow (mm runoff)	Median (**P6**) 25th-75th percentile span (**P7**)
	July flow (mm runoff)	Median (**P8**) 25th-75th percentile span (**P9**)
	October flow (mm runoff)	Median (**P10**) 25th-75th percentile span (**P11**)
Low Flow Magnitude & Frequency	Number of months that flow is less than threshold (thresholds = all-data naturalised Q95 from the baseline period)	Median (**P12**) 25th-75th percentile span (**P13**)
Minimum Flow Timing	Month (as number Jan=1, Dec=12) of minimum flow	Mode of month (**P14**)
Low Flow Duration	Number of times that two consecutive months are less than threshold (all-data naturalised Q95 from the baseline period)	Median (**P15**) 25th-75th percentile span (**P16**)

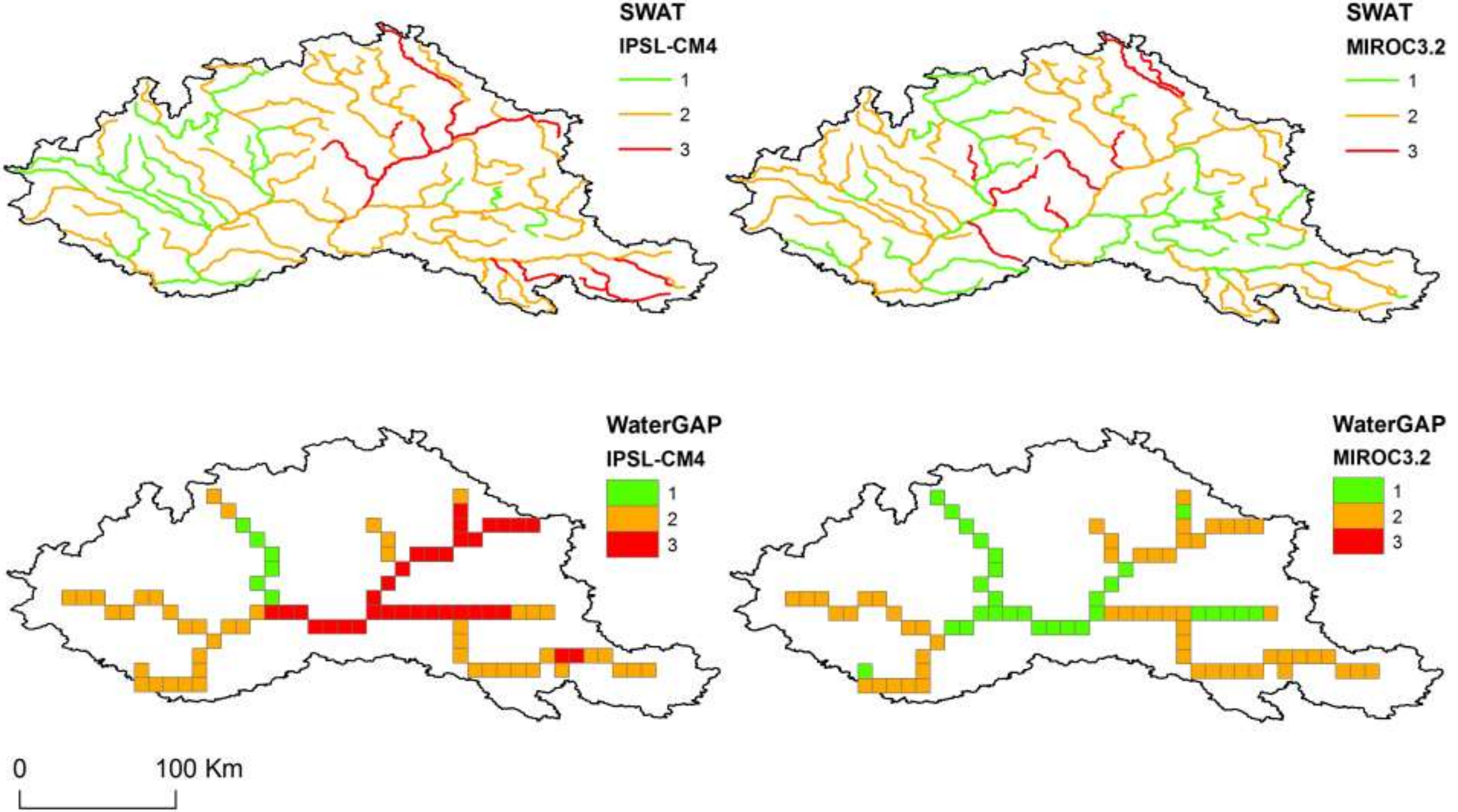
Approach - technically

- Generate monthly flow time series for the baseline period
  - SWAT 1976-2000
  - WaterGAP 1961-90
- Generate flow time series for the CC scenarios
- Read generated time series (baseline & scenarios) for selected locations into a programme calculating the impacts
- Visualize (i.e. colour coding) & analyze outputs

Results – composite e-flow index
Case 1: joint baseline period 1976-1990

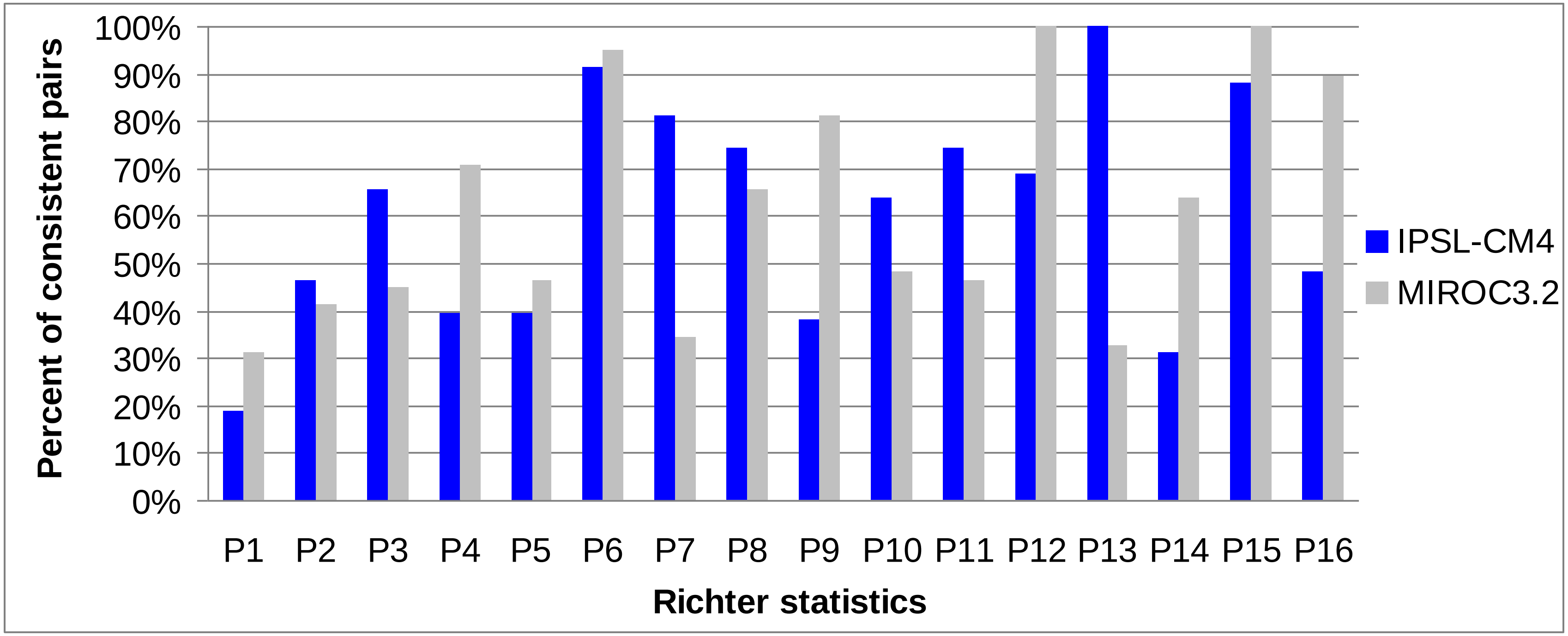


Results – composite e-flow index
Case 2: seperate baseline periods

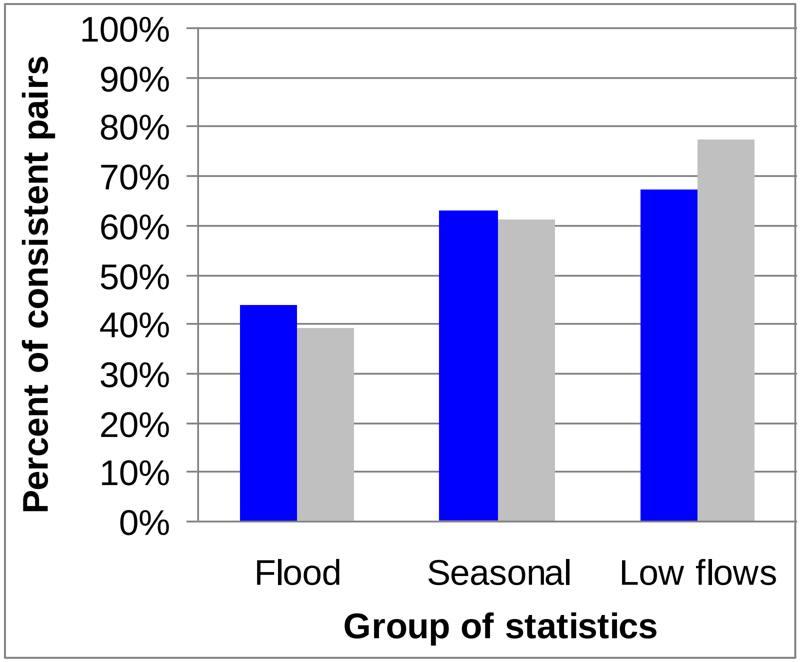


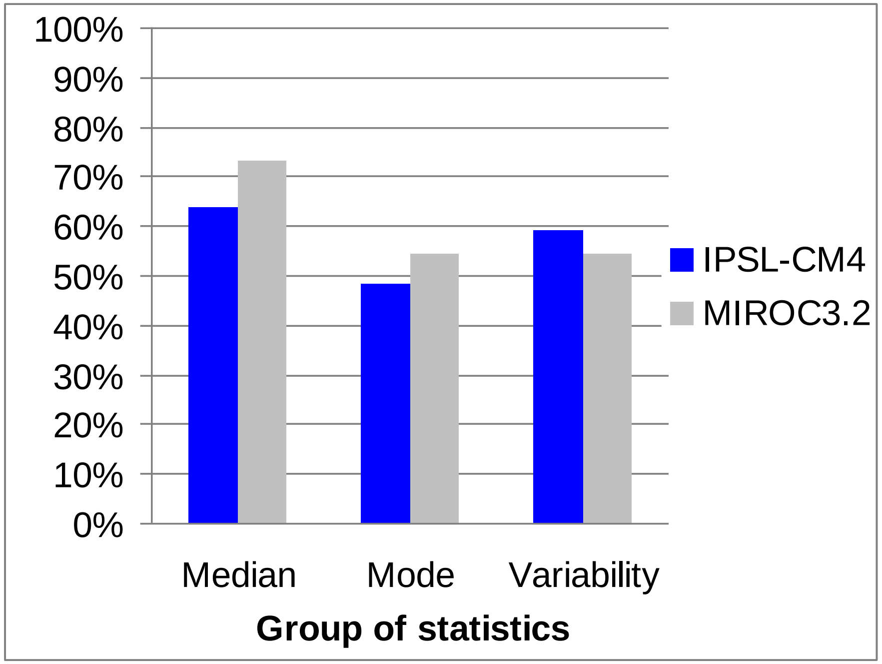
Results – individual indicators

- For a given indicator (P1 – P16), what percentage of locations on river network has consistent colour coding?

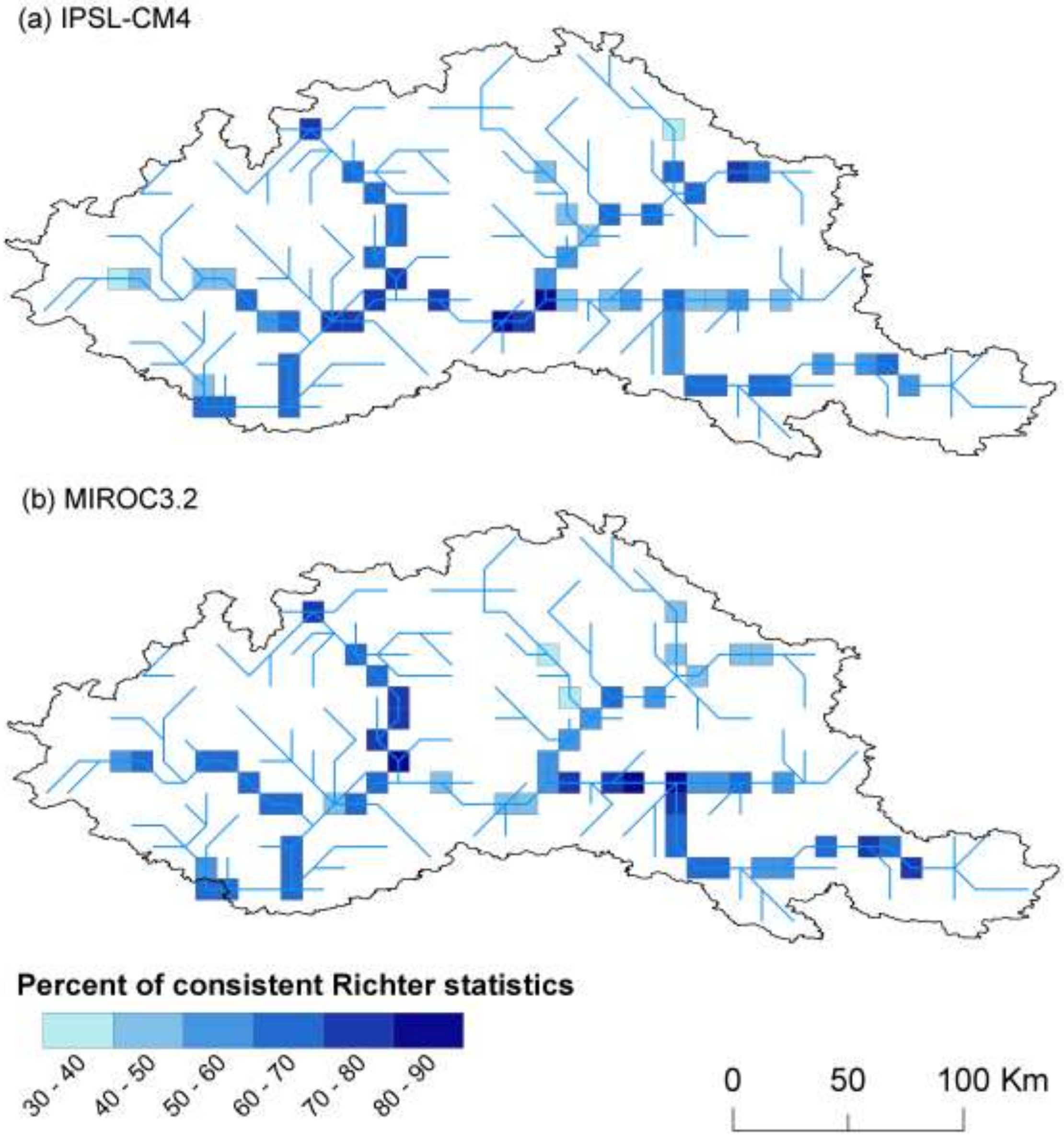


Results – groups of indicators





Results – spatial variability of consistent impacts



For a given location on river network, what percentage of indicators showed consistent impacts?

Conclusions & Outlook

- Projected impacts on environmental flows:
  - Spatially variable (from green to red)
  - Larger for IPSL-CM4 (esp. in WaterGAP)
  - Larger for joint (shorter) baseline period
- Not bad news for decision makers:
  - 66-69 % of locations with consistent colour codes
  - No location with a green colour for one model and red colour for another model
  - Good agreement for low flow indicators, worse for floods
- Future work:
  - link with ecological data – fish & floodplain wetlands (daily time scale?)
  - using more climate models

Thank you!