Characterization of climate and land use change impacts on blue and green water dynamics over the Ohio River basin

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2015/10/16

Outline

Introduction

- Blue and green water
- Objectives
- Study area and data

Methods

- Large scale SWAT model
- Trend Analysis

Results

- Climate and land use change
- Blue and green water patterns
- Combined and individual impact

Conclusion

Introduction

- Blue water
  - 1/3 of total fresh water
  - Total water yield + deep aquifer recharge
  - domestic and industrial supply
- Green water
  - Soil water content + evapotranspiration
  - vegetation growth and agriculture productivity

Previous studies **did not consider impact of time-varying land use** on long term changes of blue and green water

Objectives

- **Combined effect of climate and land use:** Analyze the spatial-temporal pattern of blue and green water in Ohio River Basin from 1935 to 2014

- **Relative effect of climate and land use:** Quantify the relative contribution of climate change or land use change on blue and green water

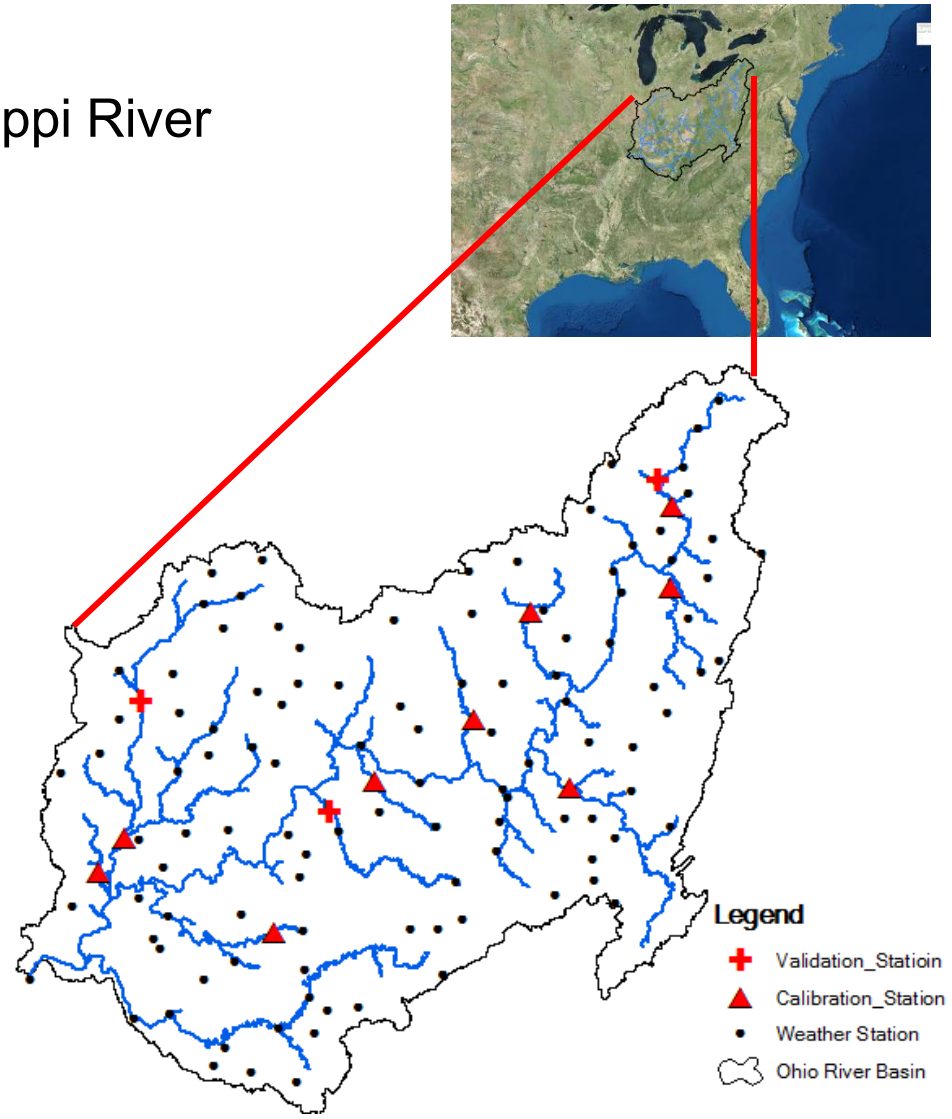
Study Area and Data

Study Area

- Ohio: largest tributary of Mississippi River
- Area: **491,000** km^2
- 10% of Mississippi River Basin
- Study period: 1935-2014

Data and Model Details

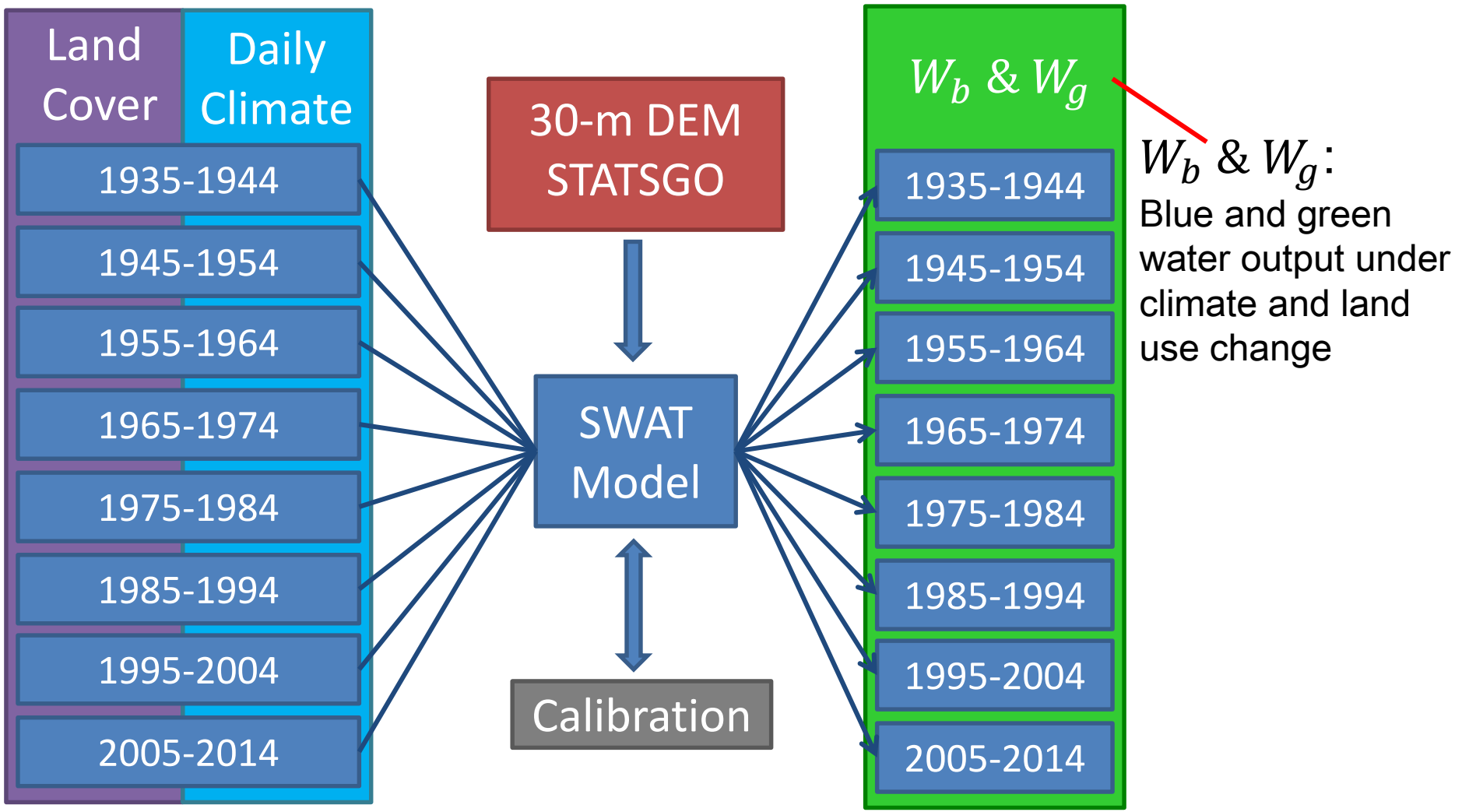
- 116 climate stations
- 8 decadal land use maps
- 125 sub-basins
- Multi-site calibration/validation
- 2 SWAT configurations



SWAT Configuration 1:

Combined effect of climate and land use change

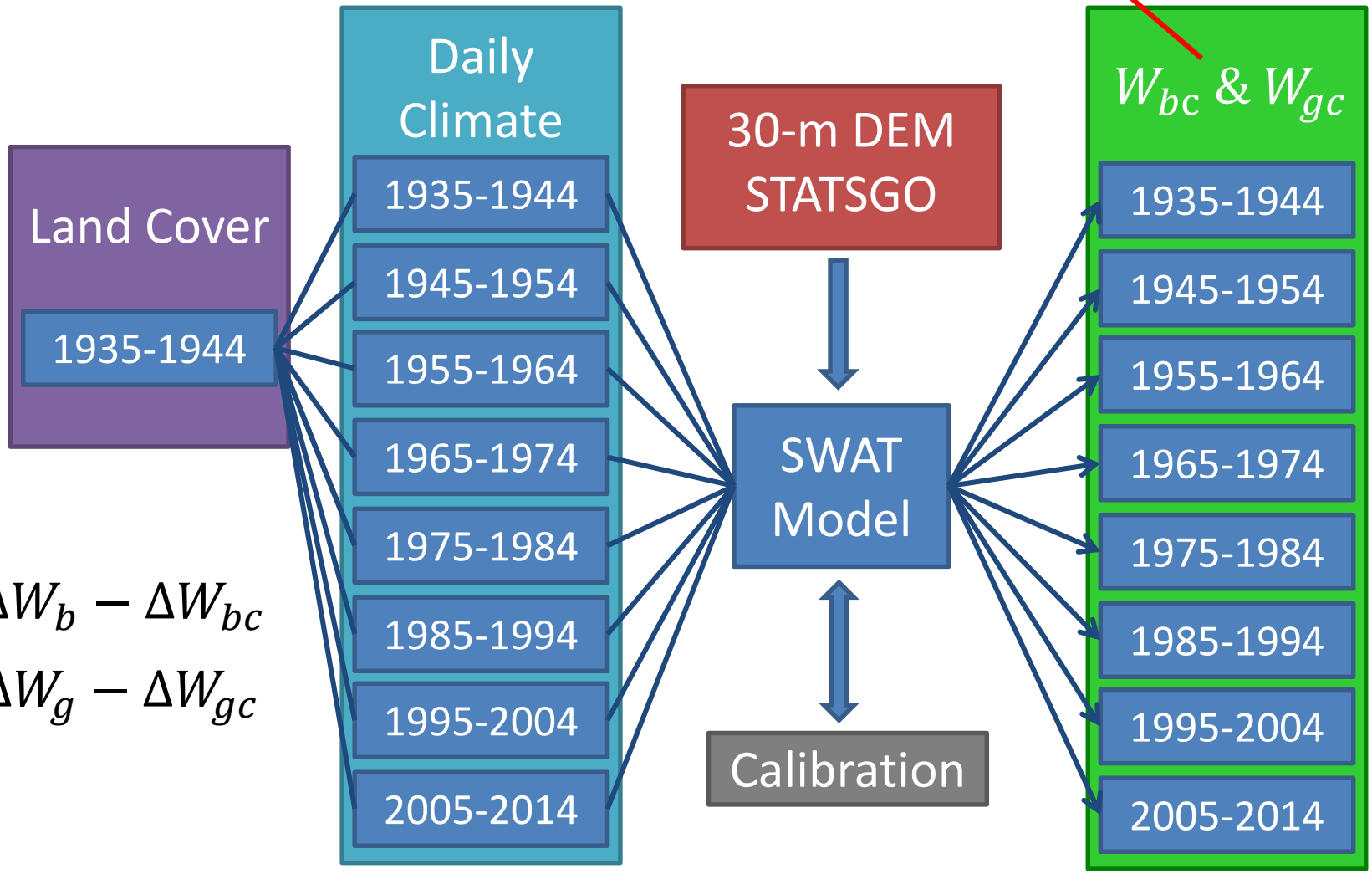
8 decadal SWAT models with 8 historical land use and 80-year climate data



SWAT Configuration 2:
Solely Climate Change

Variable climate data of 80 years with a constant land use

W_{bc} & W_{gc}:
Blue and green water output under climate change

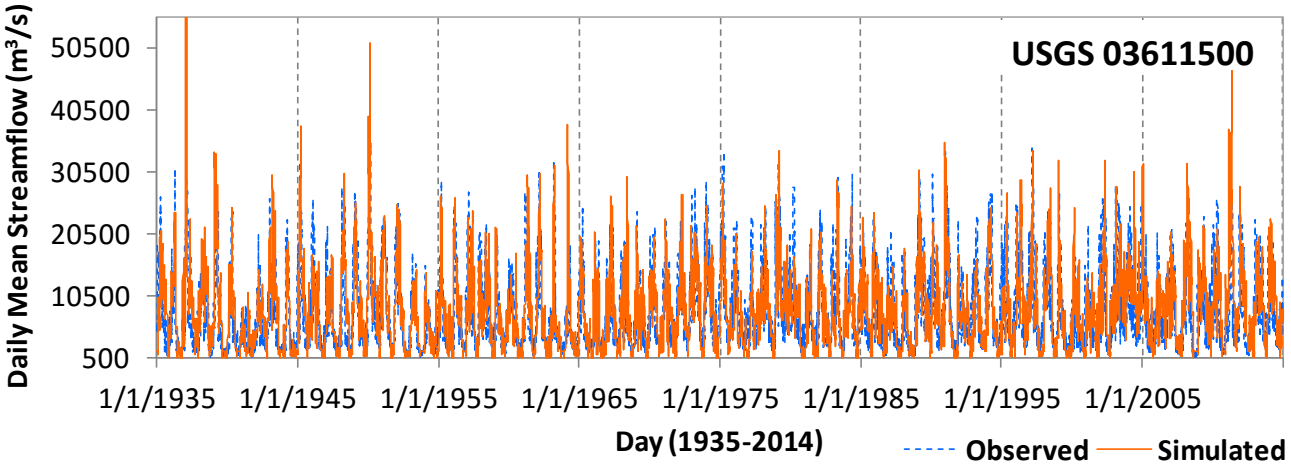


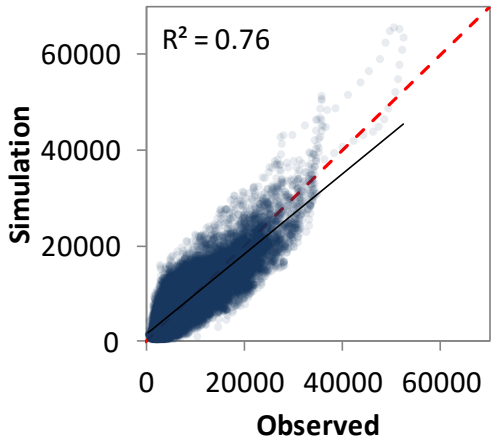
$$\Delta W_{bl} = \Delta W_b - \Delta W_{bc}$$

$$\Delta W_{gl} = \Delta W_g - \Delta W_{gc}$$

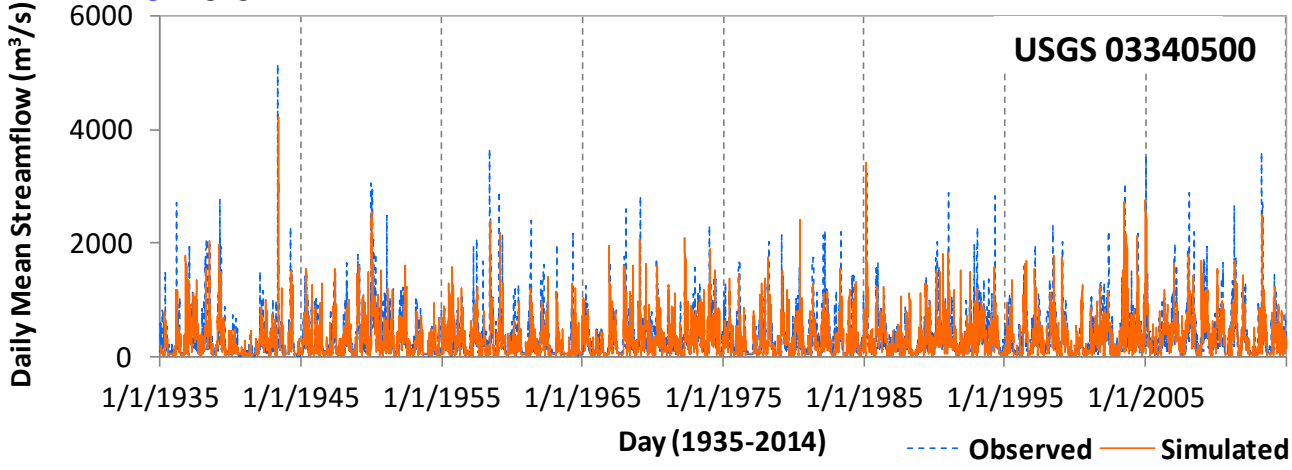
SWAT Validation

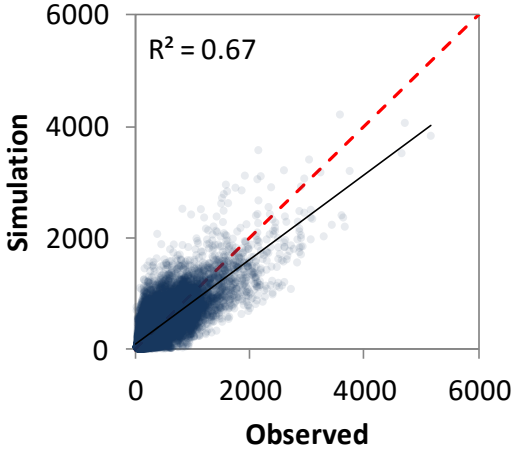
KGE	0.81	0.90	0.89	0.85	0.77	0.83	0.82	0.77
NSE	0.78	0.82	0.81	0.74	0.72	0.77	0.70	0.65





KGE	0.78	0.79	0.72	0.75	0.74	0.77	0.81	0.77
NSE	0.67	0.65	0.58	0.51	0.54	0.56	0.63	0.64

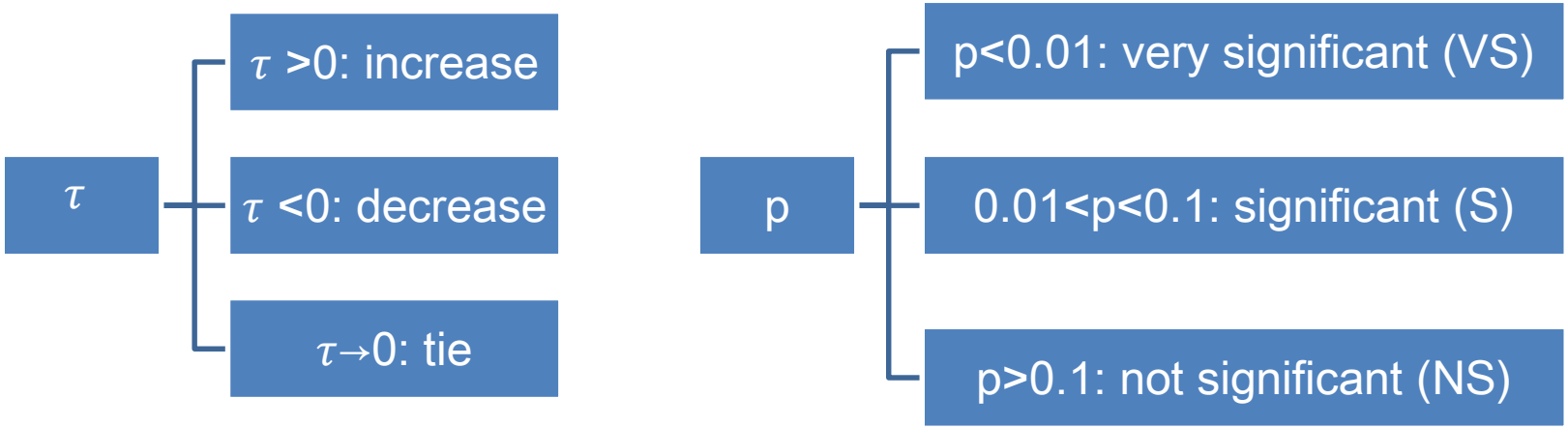




Trend Analysis

- Mann-Kendal test
  - Detect the trend of a data set

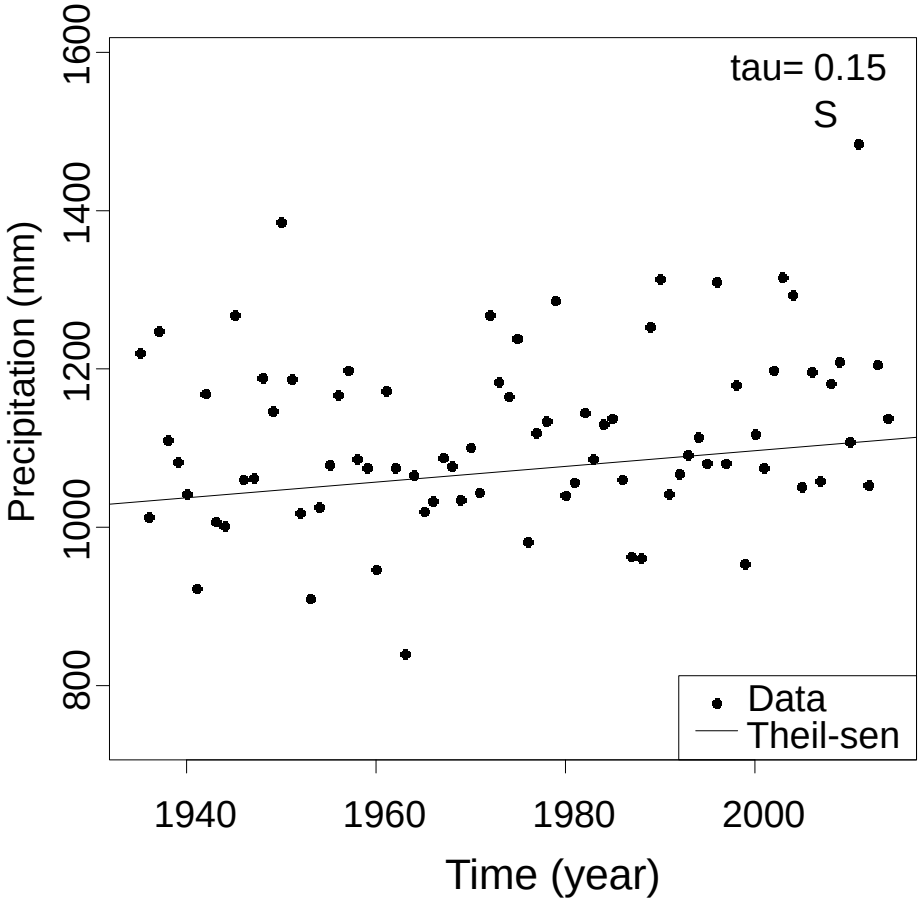
$$\tau = \sum_{i<j} (sign(x[j] - x[i]))/(\frac{n(n-1)}{2})$$

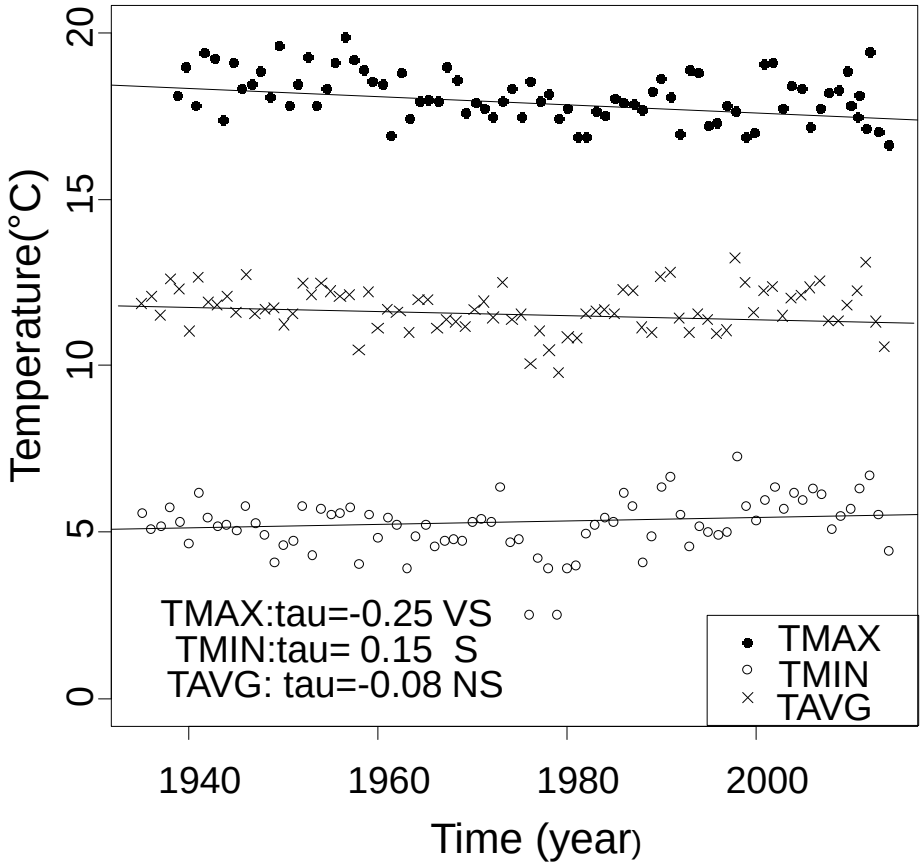


- Theil-Sen Estimator
  - Estimate the magnitude of a change

Precipitation and daily temperature

Precipitation change is the main climate change in ORB

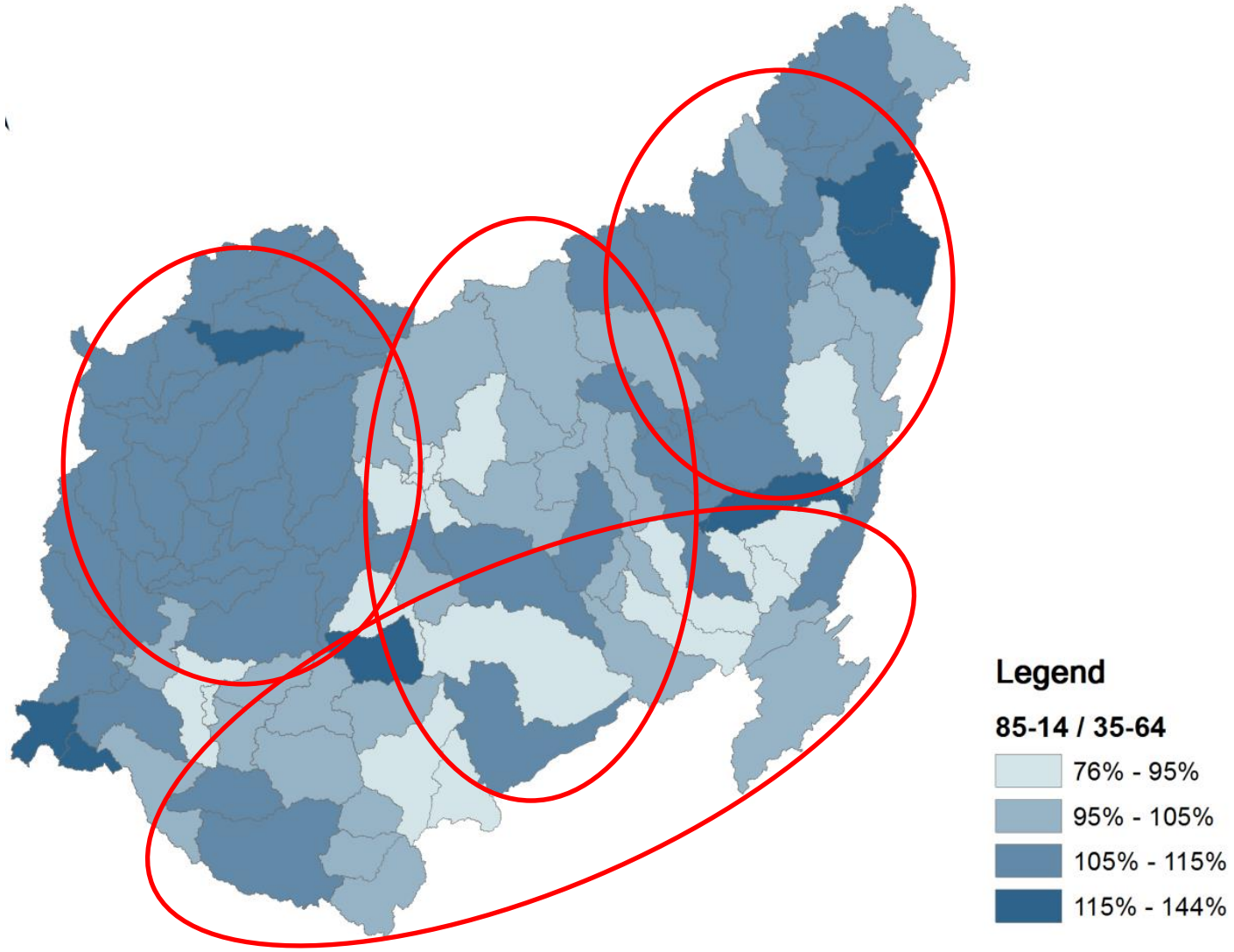




Annual average precipitation has increased by 8%

- Daily maximum temperature decreased
- Daily minimum temperature increased
- No clear trend in daily average temperature

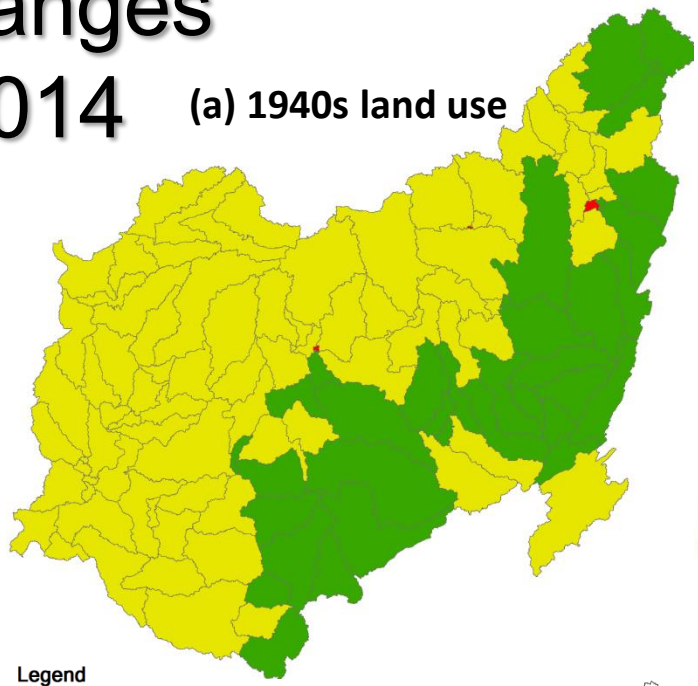
The change rate of 1985-2014 average annual precipitation with a 1935-1964 precipitation baseline

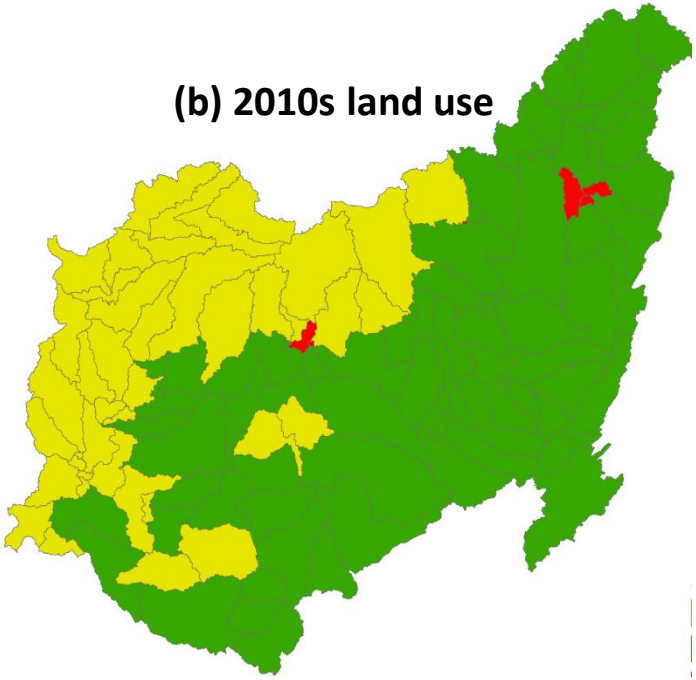


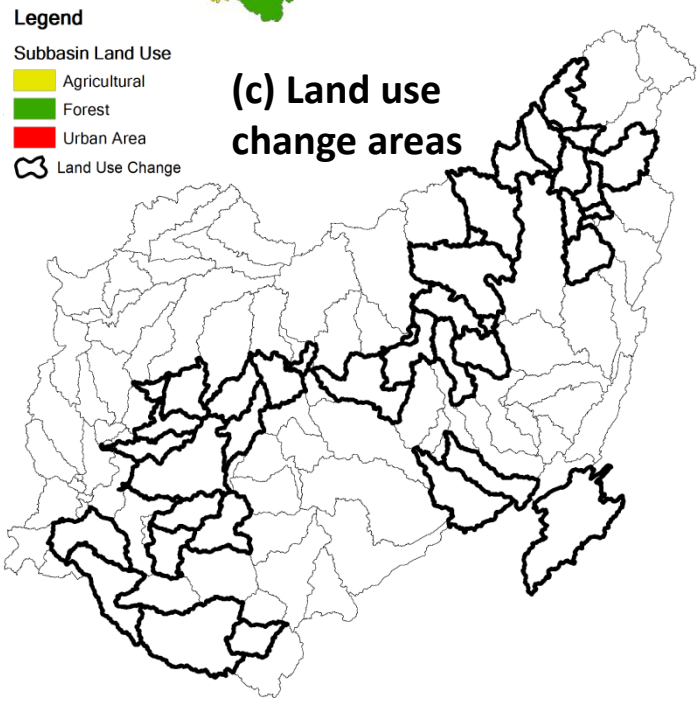
Land use changes in 1935-2014

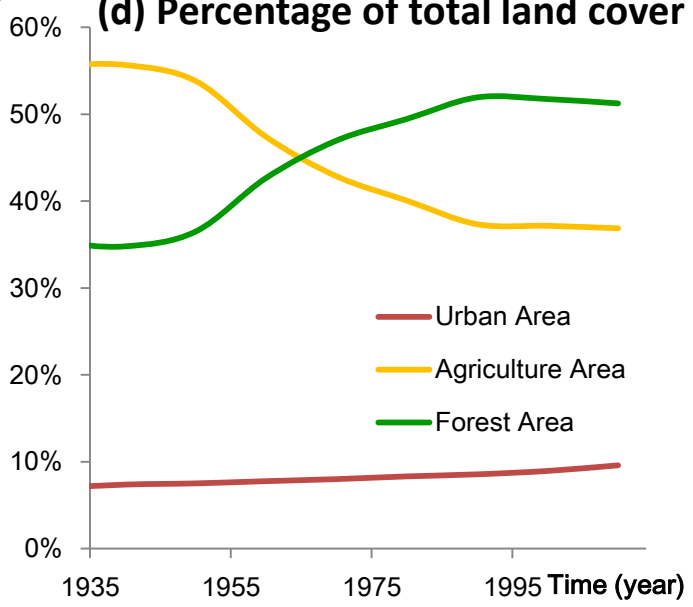
Main land use change is from agriculture to forest.

Most changes occur in the middle of the basin.

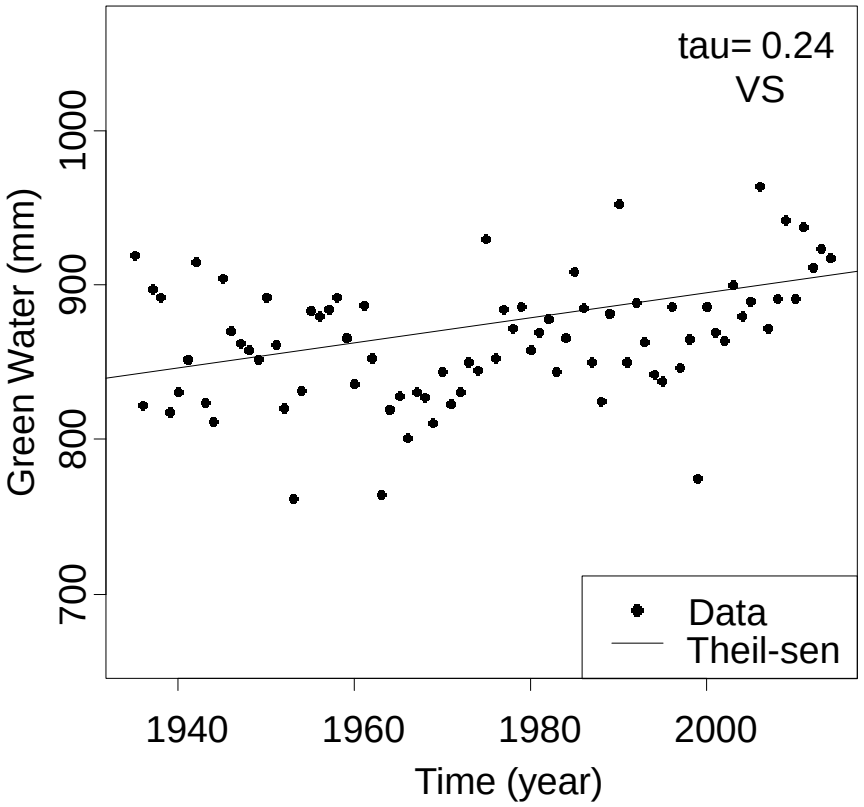


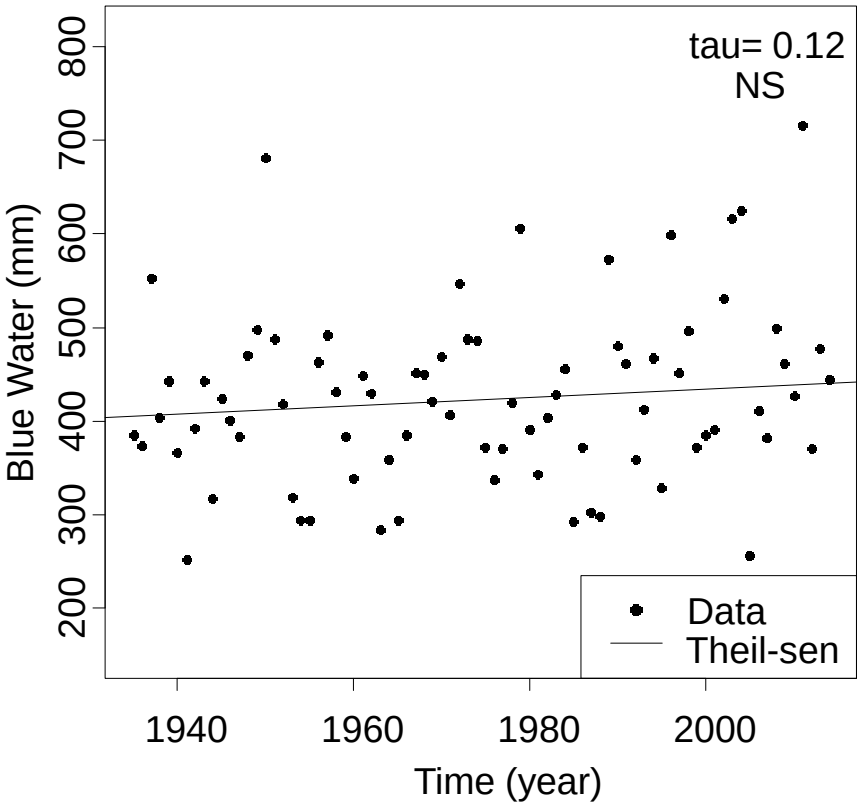






MK results for green water and blue water in the basin level



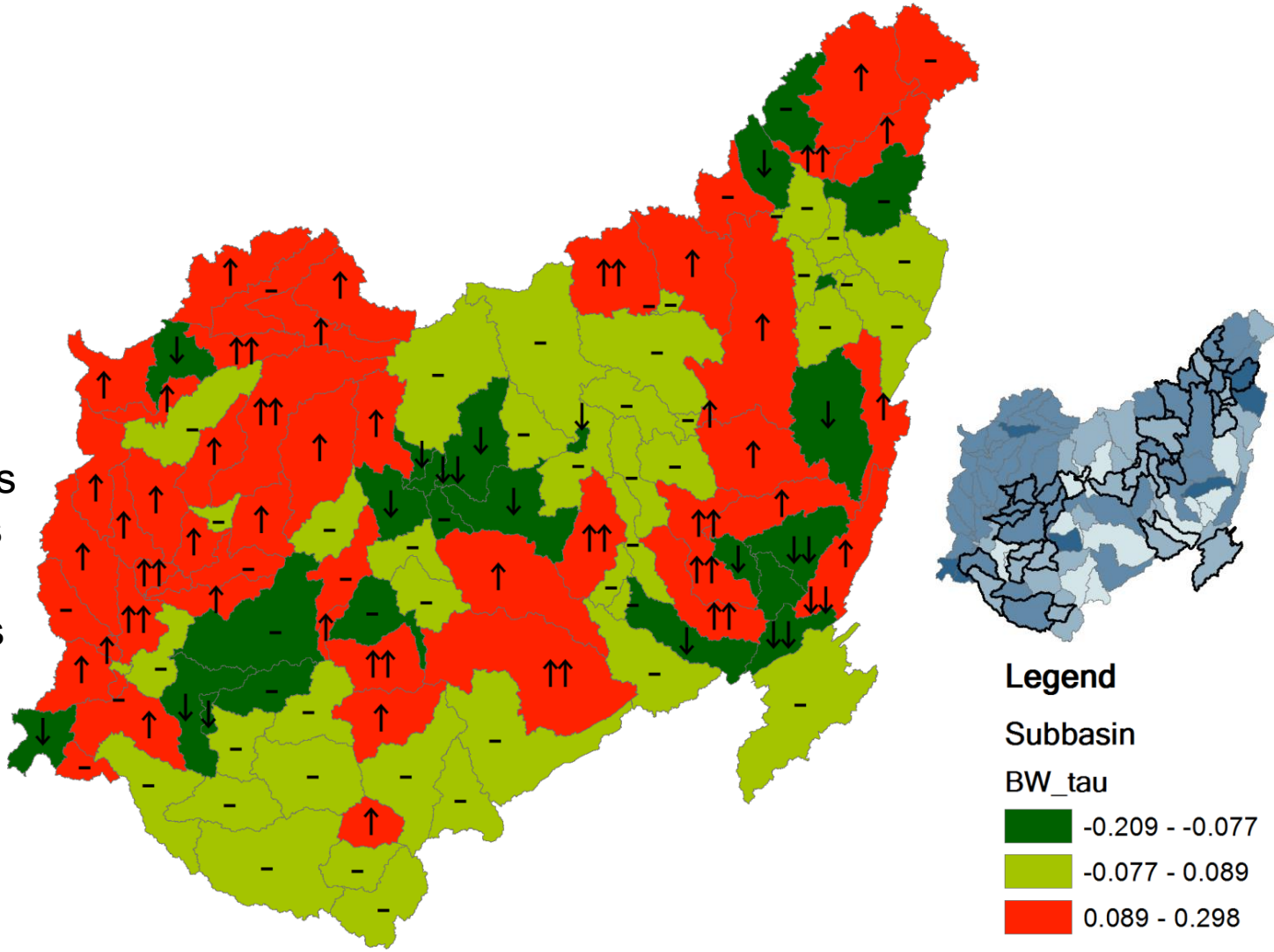


More available water for vegetation and crop growth

Stable water resources for domestic and industrial usage

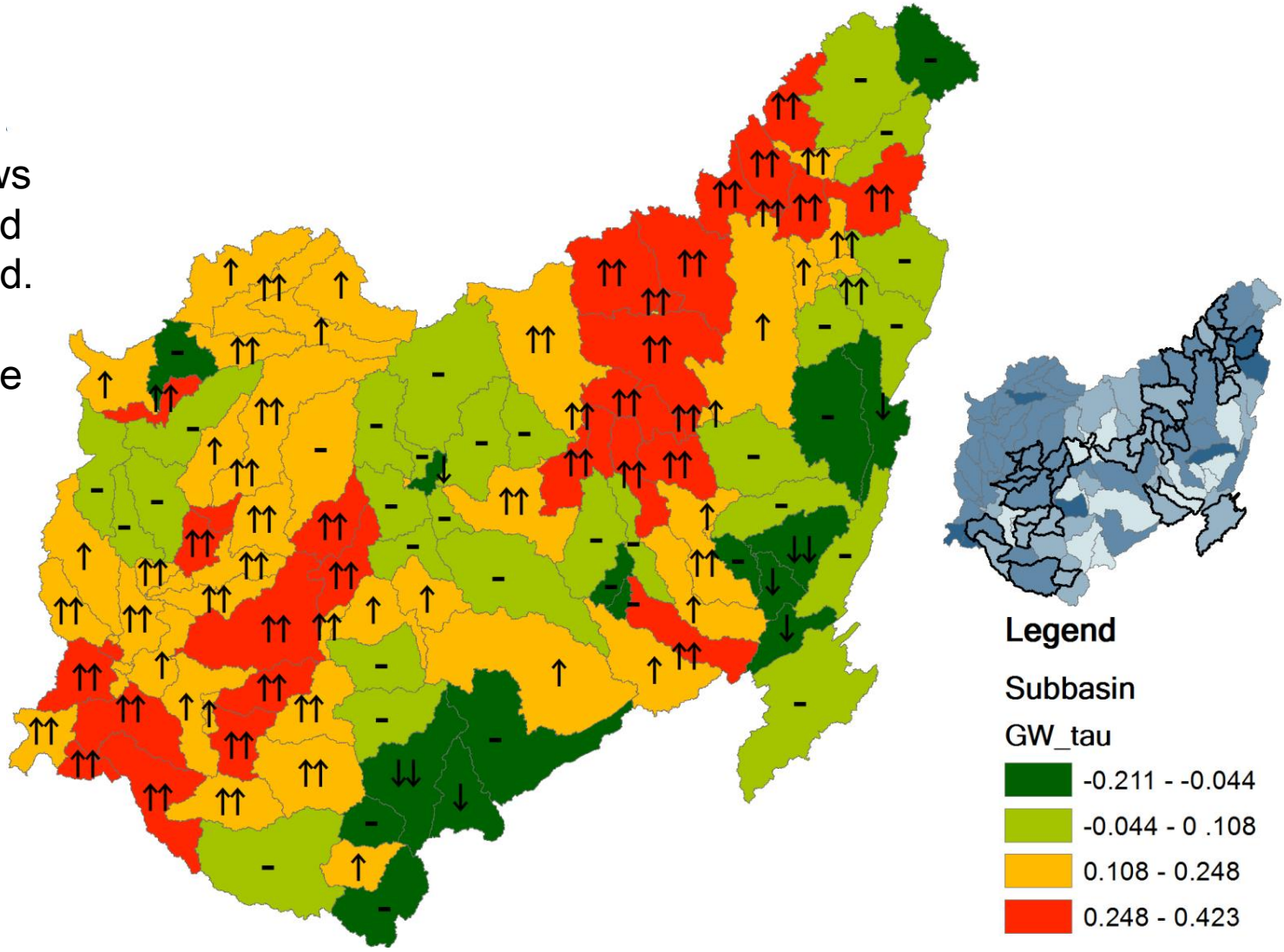
MK result of blue water in the subbasin level

- Blue water flows increase in the northwest and northeast
- Decreasing blue water band lies between two increasing regions
- Combined results from climate and land use changes



MK result of green water in the subbasin level

- Most increasing green water flows occur where land use has changed.
- Green water decreases where precipitation decreases.



Upper, middle, and lower region

Upper Region

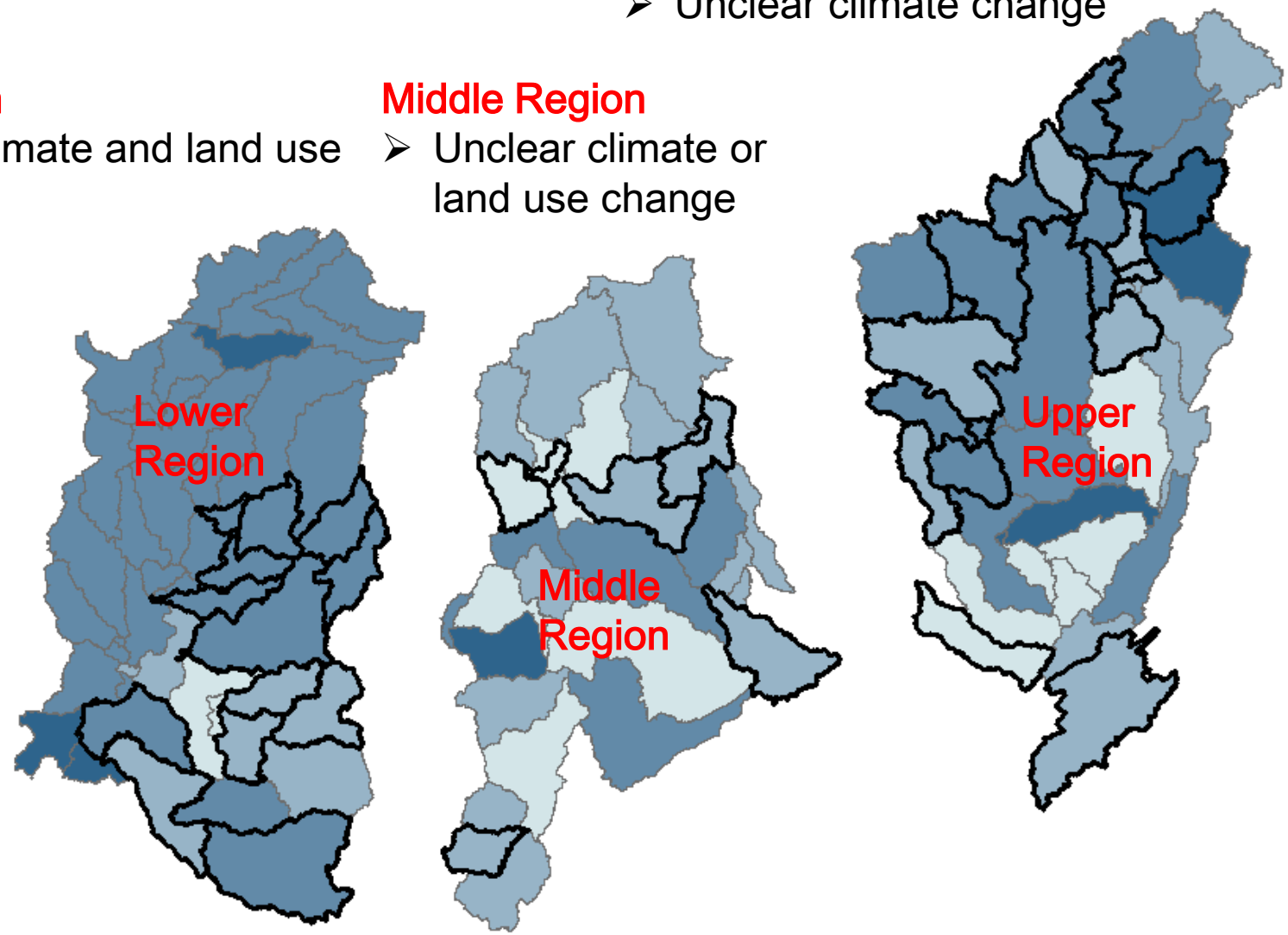
- Obvious land use change
- Unclear climate change

Lower Region

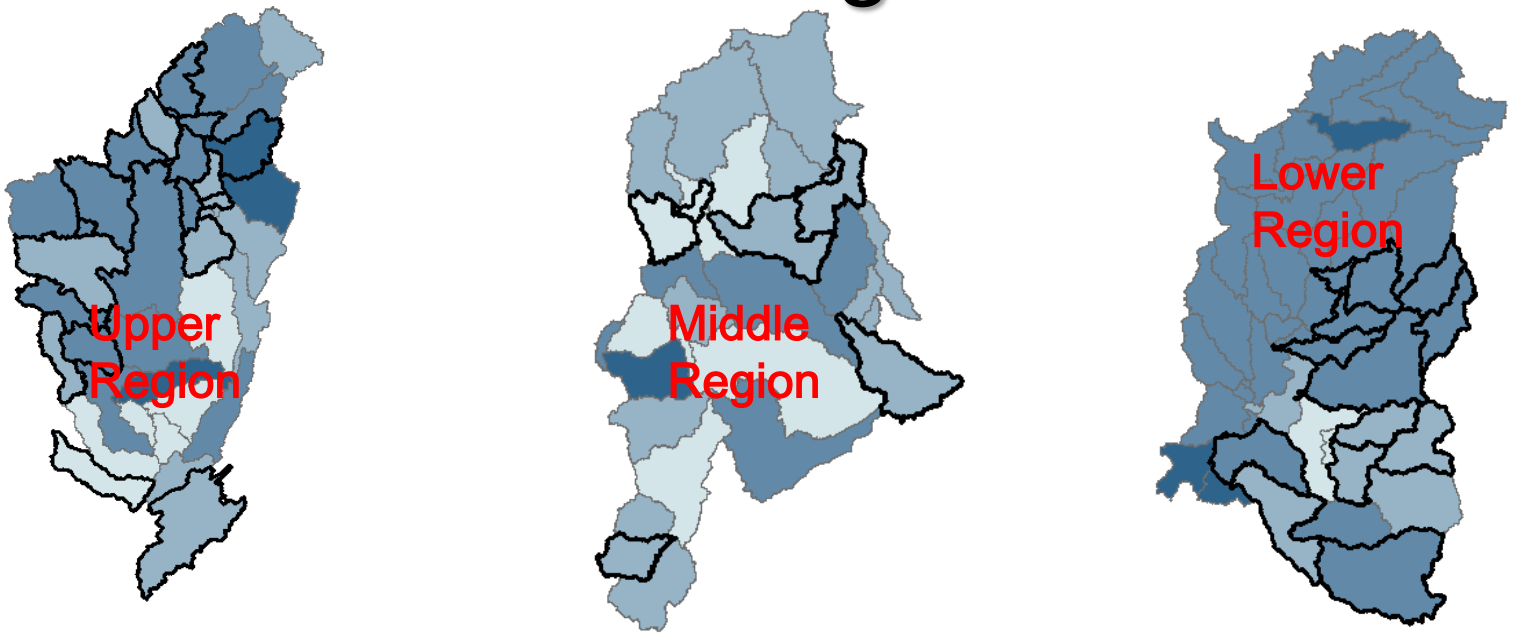
- Obvious climate and land use change

Middle Region

- Unclear climate or land use change



MK results for green water and blue water in the regional level



	Upper Region		Middle Region		Lower Region	
	tau	significance	tau	significance	tau	significance
Green Water	0.19	S	0.1	NS	0.31	VS
Blue Water	0.08	NS	0.04	NS	0.14	S

Correlating climate and land use with blue and green water in ORB

- Climate change has a more substantial impact on blue water than green water.
- Land use change influences positively on green water, but negatively on blue water.

Relative contribution of climate impacts and land use impacts

	($\times 10^9 m^3$)	Total Change	Change by Climate	climate Impacts	Land Use Impacts
Entire Basin	Green Water	27.29*	2.91	11%	89%
	Blue Water	15.02	20.9^+	78%	-22%

* significant at $p<0.01$
+ significant at $p<0.1$
- the impact leads to a decrease

Relative contribution of climate impacts and land use impacts on the water components

	($\times 10^9 m^3$)	Total Change	Change by Climate	climate Impacts	Land Use Impacts
Blue Water	Total Water Yield	17.23	21.06+	85%	-15%
Blue Water	Deep Aquifer Recharge	0.87+	0.39+	45%	55%
Green Water	Soil Water	4.22+	7.61*	69%	-31%
Green Water	Actual Evapotranspiration (ET)	14.73+	-0.12	-1%	99%

* significant at $p<0.01$
+ significant at $p<0.1$
- the impact leads to a decrease

Conclusion

- Remarkable Change of Climate and Land Use
- Blue Water and Green Water Change
  - Increase for the entire basin
  - Blue water: significant increase in lower region
  - Green water: significant increase in upper and lower regions
- Relative Contribution
  - Climate: dominant on blue water
  - Land use: foremost on green water, negative on blue water
- Provide information to take mitigating measures depending on locations and governing factors

Thank you!

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