VIETNAM INSTITUTE OF METEOROLOGY, HYDROLOGY AND ENVIRONMENT

CENTER FOR HYDROMET AND ENVIRONMENT CONSULTANCY

DETECTION OF TRENDS IN TEMPERATURE, RAINFALL AND STREAMFLOW IN THE RED RIVER BASIN

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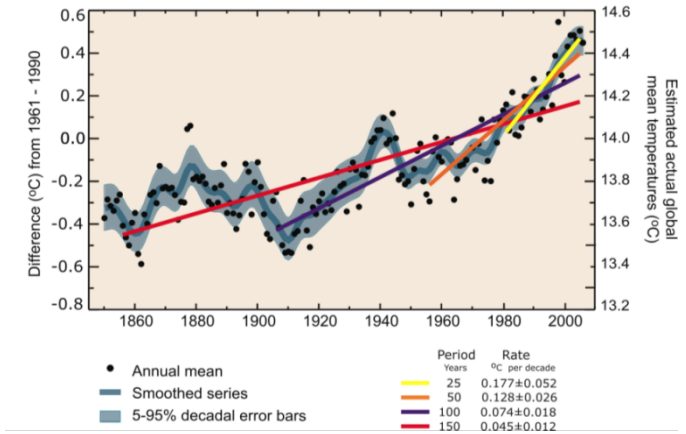
Content

- Background
- Description of study area
- Methodology
- Results
- Conclusions and Outlook

Background

- Vietnam is among the countries most heavily affected by the consequences of climate change
- The detection of trends in hydro-climatic data is essential for the assessment of the impacts of climate variability and change on the water resources of a region.
- In Vietnam, few studies of streamflow trends have been published.

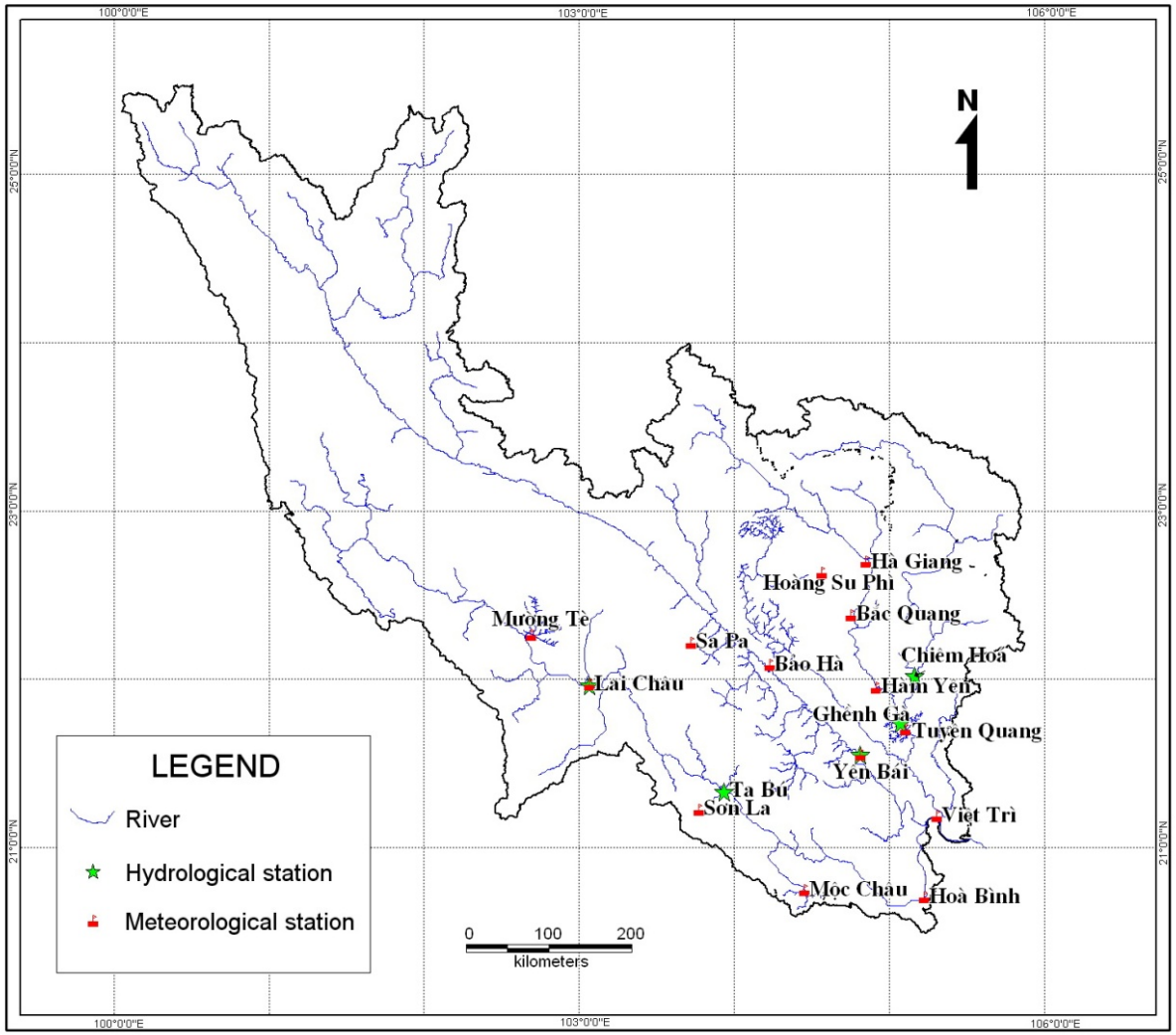


Objectives

- Determine temperature, rainfall and streamflows trends in the Red River Basin:
  - Analyze annual trends of temperature, rainfall and streamflows;
  - Analyze seasonal trends of temperature, rainfall and streamflows.

Description of study area

- F = 169,000 km^2 (Vietnam: 51%);
- Climate: moonson tropical;
- Average temperature: 15°C – 26°C;
- Annual rainfall: 1,500 mm (Bac Quang: 4,800 mm);
- Mean dischagre: 3600 m^3/s (min: 370 m^3/s; max: 38,000 m^3/s);



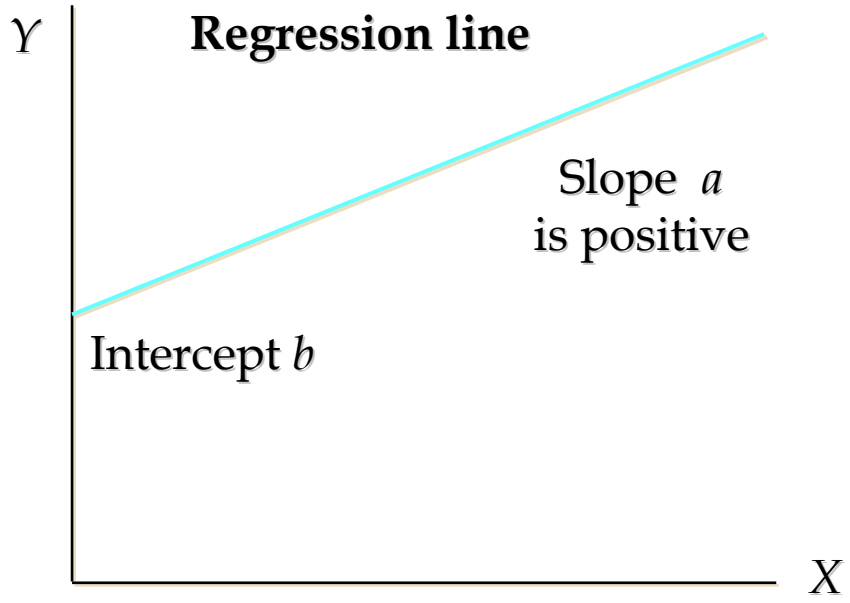
Methodology

- Linear regression

$$Y = aX + b$$

  - X=time (year); a=slope coefficients;
  - b=least-square estimates of the intercept.

- Assumptions:
  - observations must be independent;
  - normally distributed populations;
  - constant variance.



Methodology

- Linear regression
  - statistical significant test:

$$S = \frac{a}{\sigma}$$

where

$$\sigma = \sqrt{\frac{12 \sum_{i=1}^{n} (y_i - b - ax_i)}{n(n-2)(n^2-1)}}$$

Methodology

- Mann-Kendall

$$S = \sum_{i=2}^{n} \sum_{j=1}^{i-1} \text{sign}\left(x_i - x_j\right)$$

where

$$\text{sign}\left(x_i - x_j\right) = \begin{cases} 1 & \text{if} \quad x_i > x_j \\ 0 & \text{if} \quad x_i = x_j \\ -1 & \text{if} \quad x_i < x_j \end{cases}$$

Methodology

- Mann-Kendall
  - S has a normal distribution with the mean value μ_s and variance σ_s^2:

$$\mu_s = 0$$

$$\sigma_s^2 = \frac{n(n-1)(2n+5)}{18}$$

  - statistical significant test:

$$Z = |S| / \sigma^{0.5}$$

Methodology

- Serial correlation
  - positive serial correlation increases the probability that the MK test detects a trend when it doesn't exist;
  - prewhitening approach:

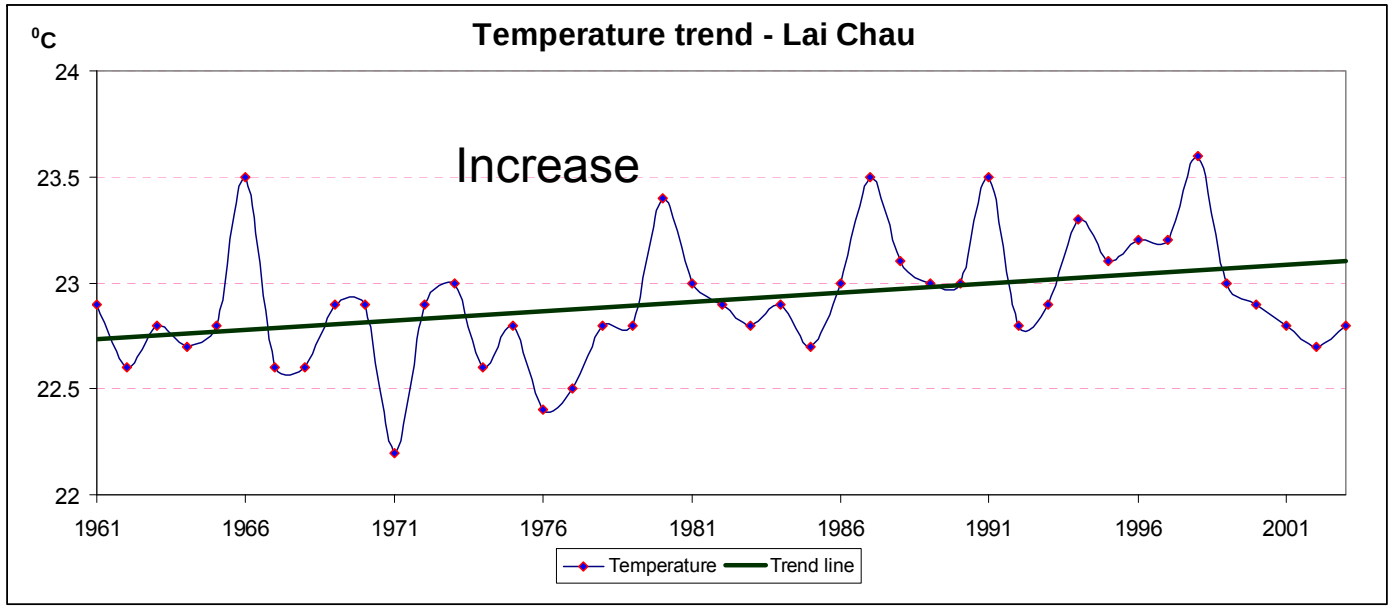
$$x_t^* = x_t - r_1 x_{t-1}$$

where

r_1 = AR(1)

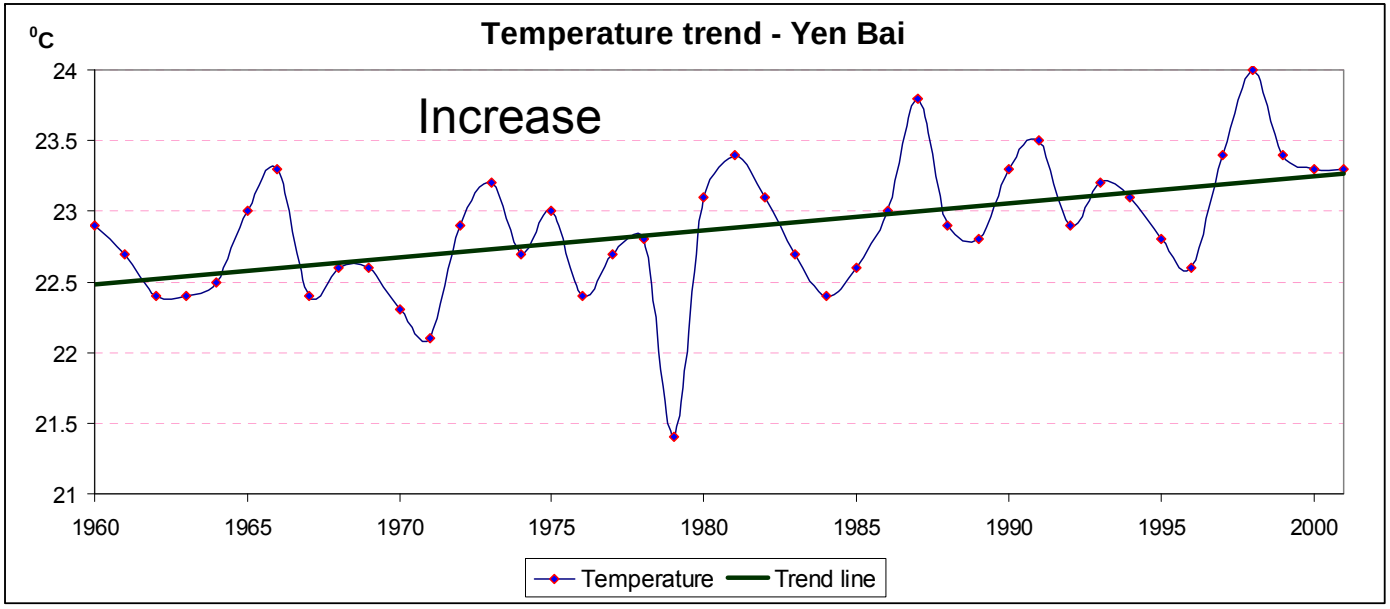
Results

- Temperature
  - Linear regression



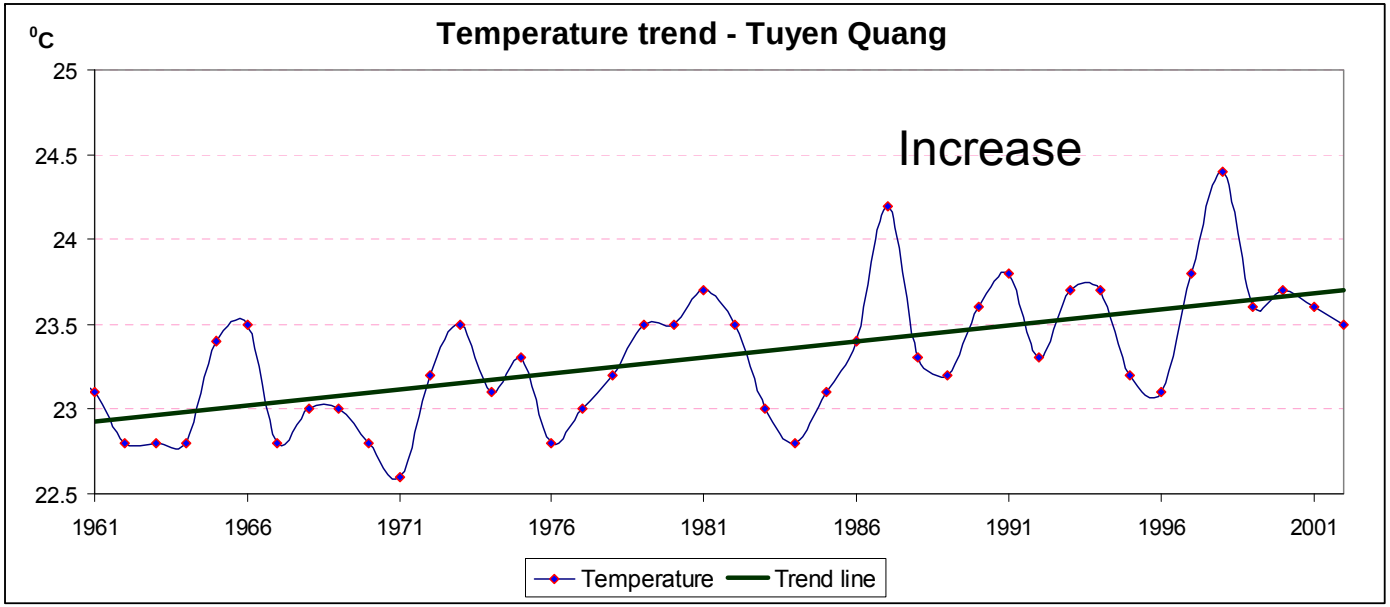
Results

- Temperature
  - Linear regression



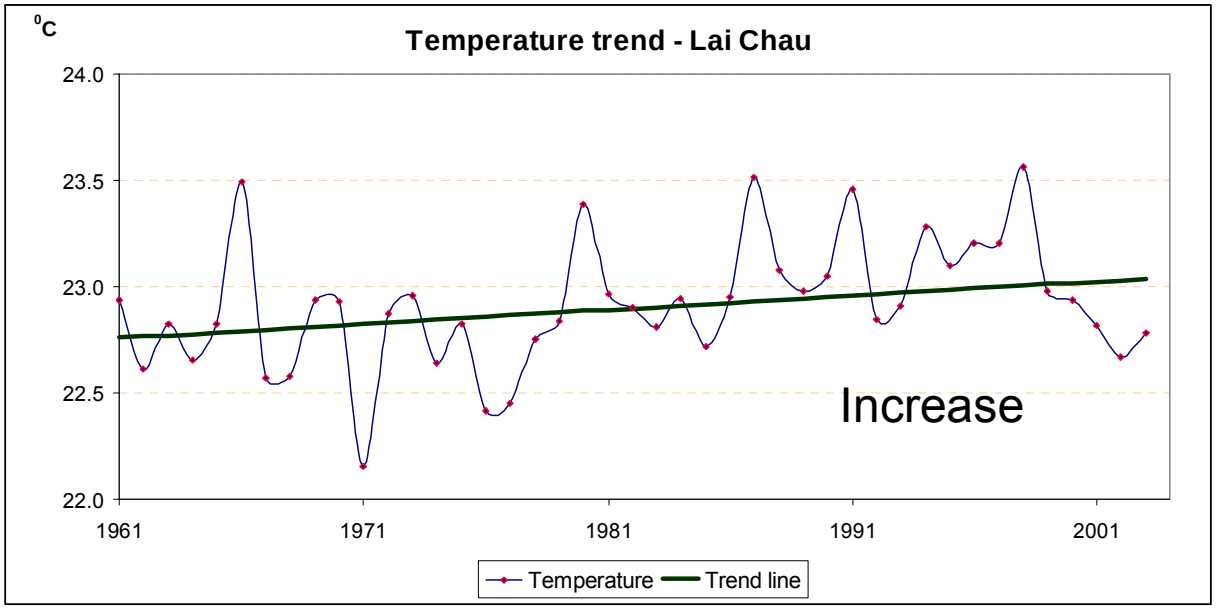
Results

- Temperature
  - Linear regression



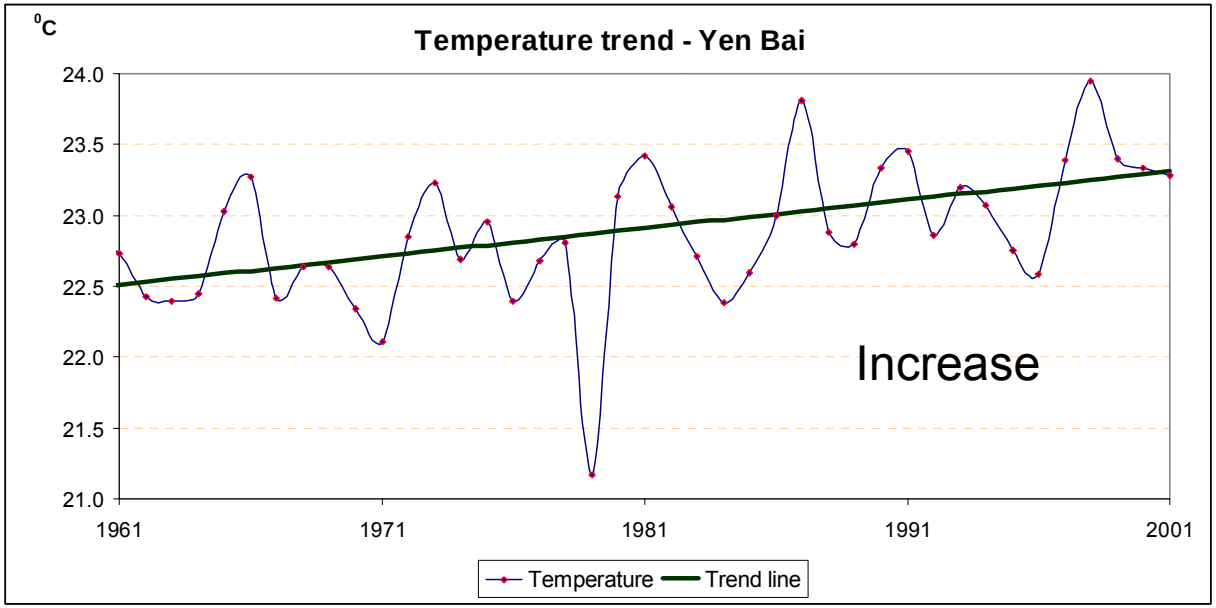
Results

- Temperature
  - Mann-Kendall



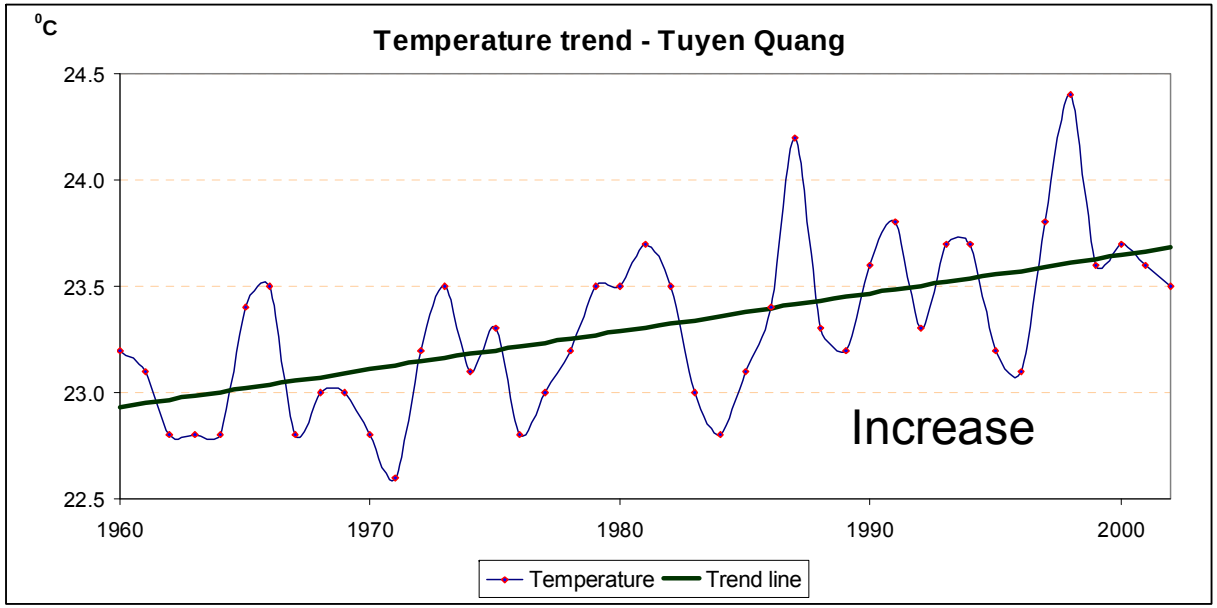
Results

- Temperature
  - Mann-Kendall



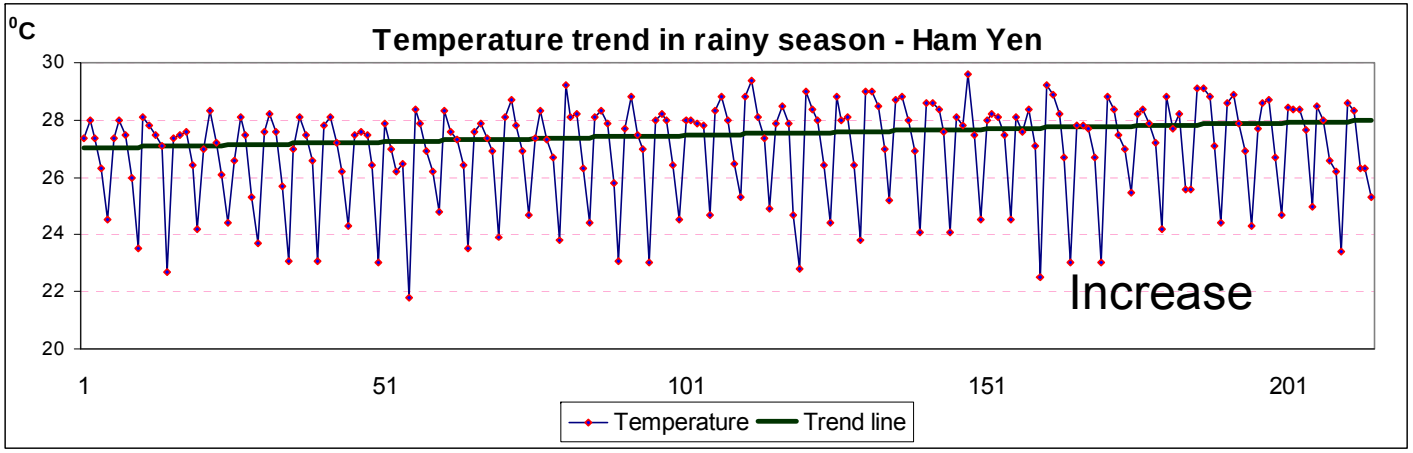
Results

- Temperature
  - Mann-Kendall



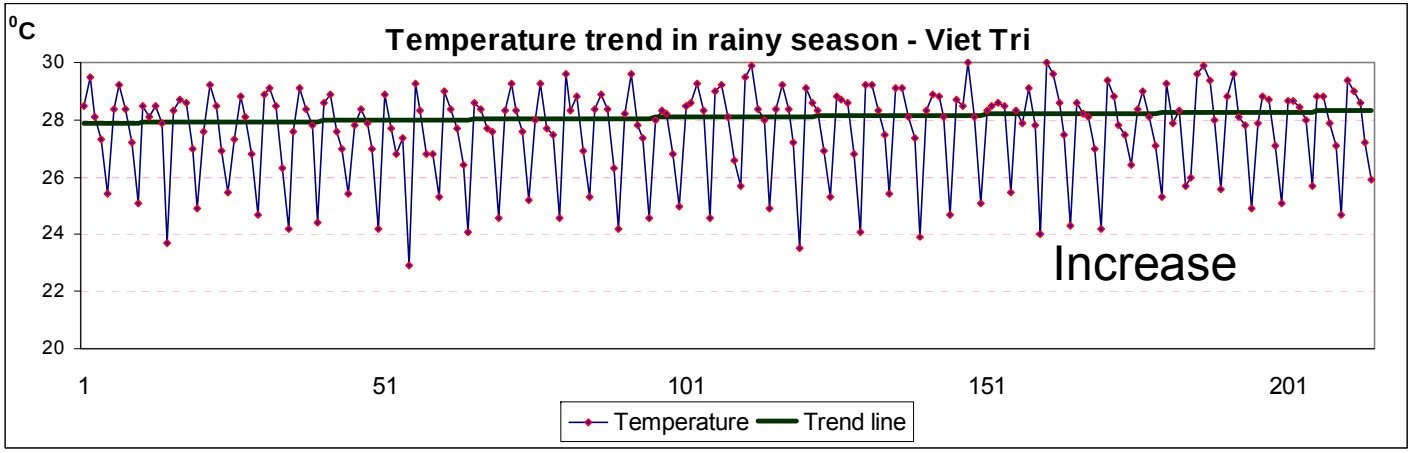
Results

- Temperature
  - Seasonal Mann-Kendall



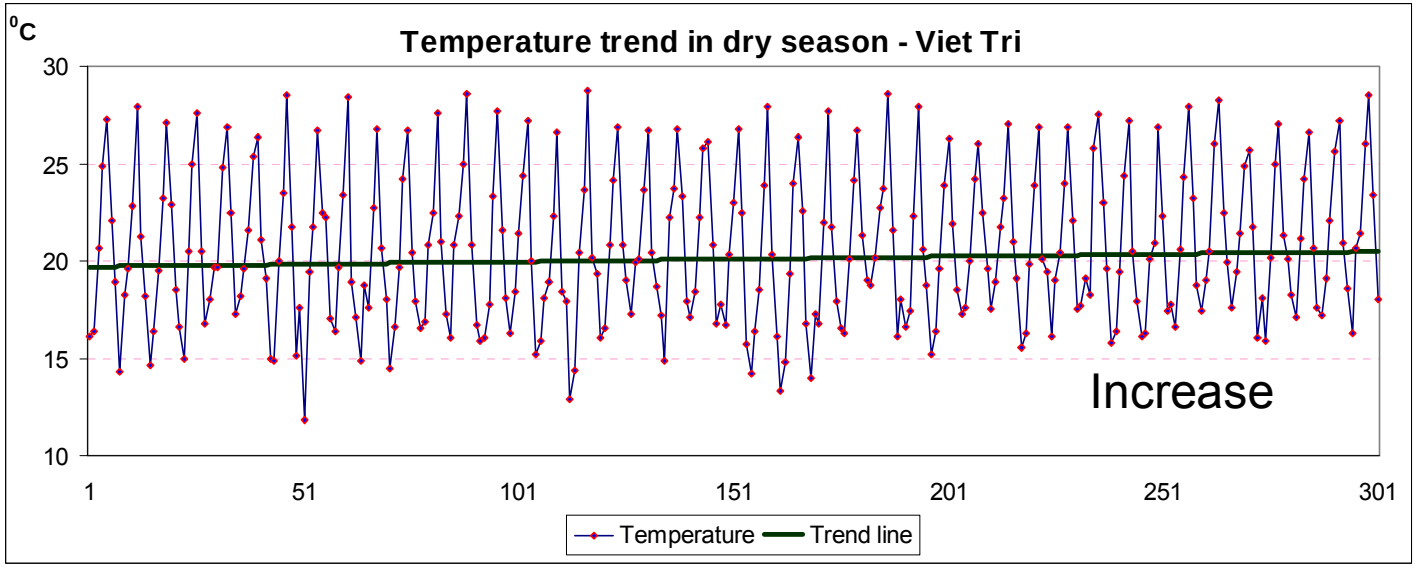
Results

- Temperature
  - Seasonal Mann-Kendall



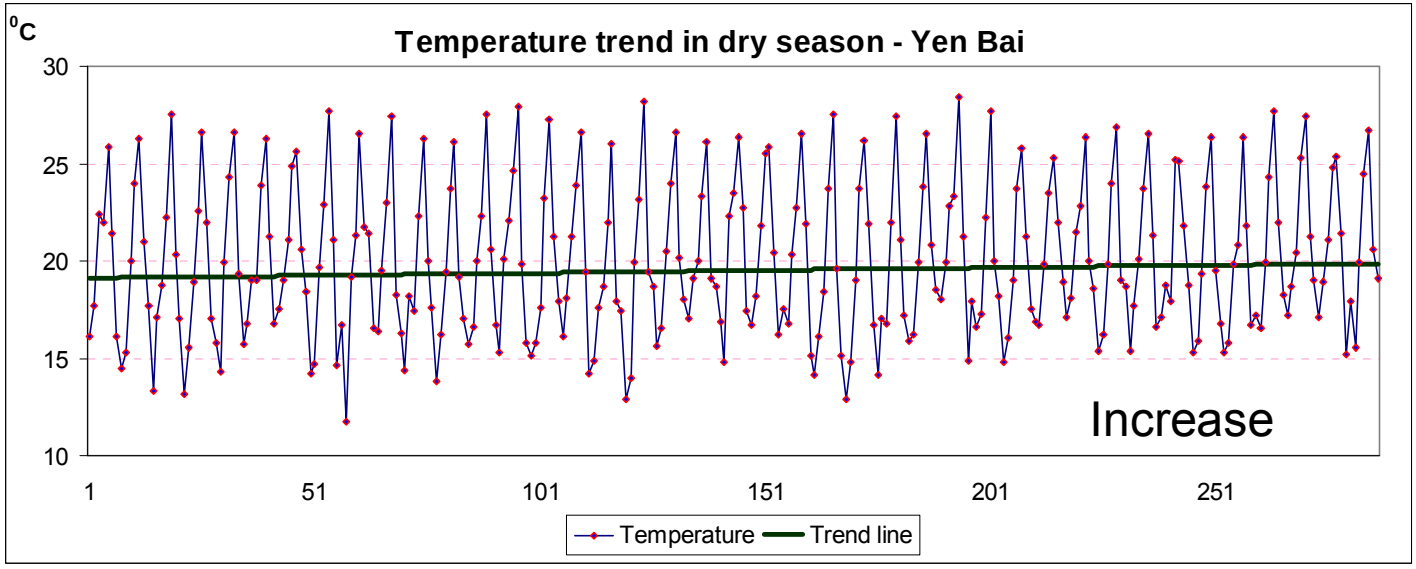
Results

- Temperature
  - Seasonal Mann-Kendall



Results

- Temperature
  - Seasonal Mann-Kendall



Results

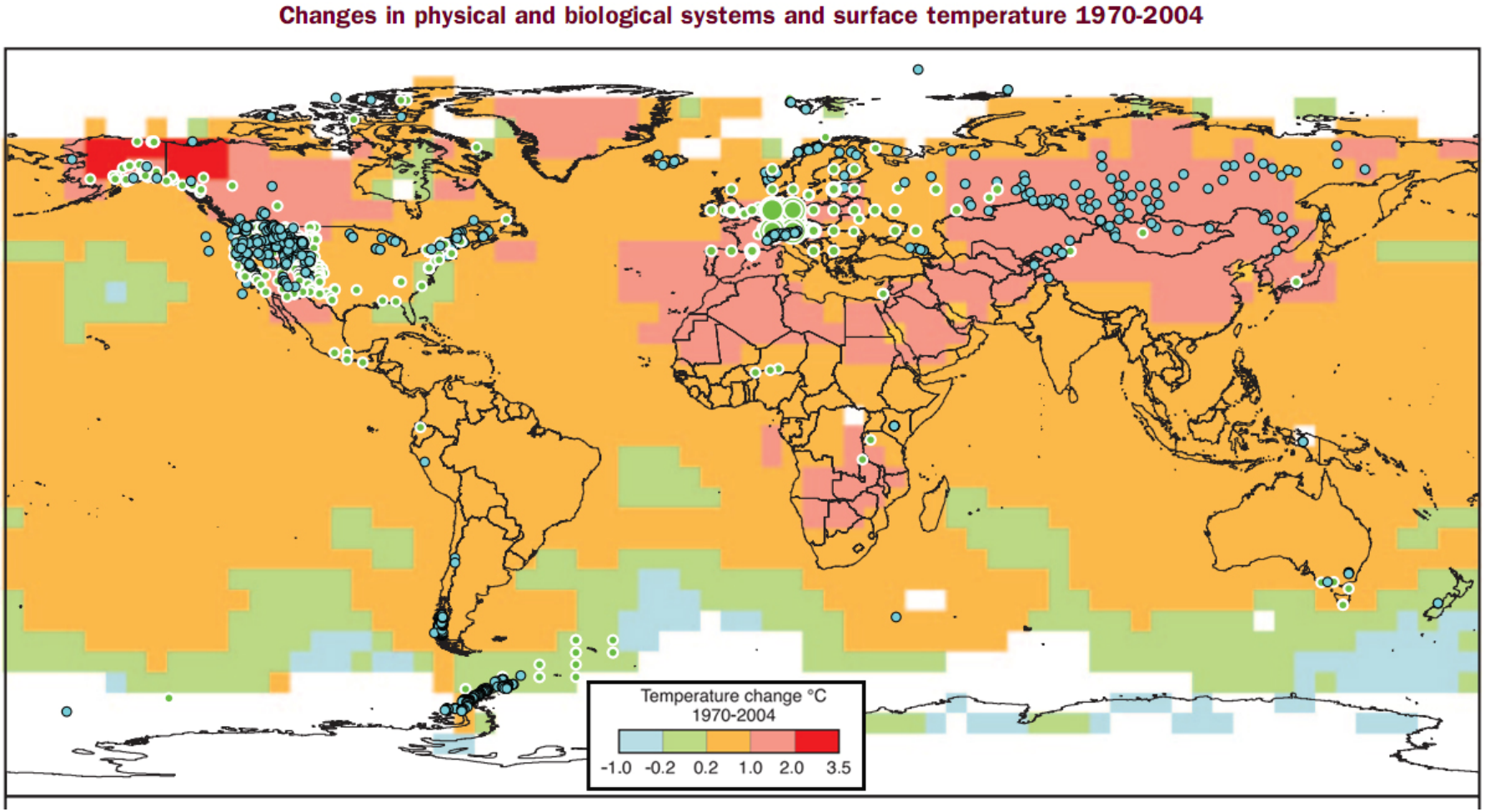
- Temperature

Trend analysis for temperature

No	Station	Linear regression			Mann-Kendall				Seasonal Mann-Kendall							
									Dry season				Rainy season			
		Sigma	S	Trend	S	Z	P	Trend	S	Z	P	Trend	S	Z	P	Trend
1	Bao Ha	0.007	3.345	Increasing	2160	6.773	0	Increasing	883	3.493	0.0005	Increasing	1364	6.411	0	Increasing
2	Bac Quang	0.004	6.128	Increasing	2521	7.9101	0	Increasing	1248	5.114	0	Increasing	1286	6.25	0	Increasing
3	Ham Yen	0.005	6.219	Increasing	2840	8.596	0	Increasing	1418	5.614	0	Increasing	1422	6.672	0	Increasing
4	Hoa Binh	0.005	4.268	Increasing	2594	7.088	0	Increasing	1018	3.64	0.0003	Increasing	1575	6.666	0	Increasing
5	Hoang Su Phi	0.004	3.979	Increasing	1530	4.793	0	Increasing	800	3.277	0.001	Increasing	752	3.651	0.0003	Increasing
6	Lai Chau	0.003	2.511	Increasing	857	2.499	0.0124	Increasing	521	1.988	0.0468	Increasing	344	1.552	0.1207	No trend
7	Muong Te	0.003	3.116	Increasing	1303	3.802	0.0001	Increasing	461	1.762	0.078	Increasing	848	6.832	0.0001	Increasing
8	Tuyen Quang	0.004	4.846	Increasing	2155	6.302	0	Increasing	1018	3.892	0.0001	Increasing	1137	5.156	0	Increasing
9	Viet Tri	0.005	3.332	Increasing	1488	4.502	0	Increasing	816	3.229	0.0012	Increasing	672	3.15	0.0016	Increasing
10	Yen Bai	0.005	3.604	Increasing	1781	5.615	0	Increasing	728	3.091	0.002	Increasing	946	4.764	0	Increasing

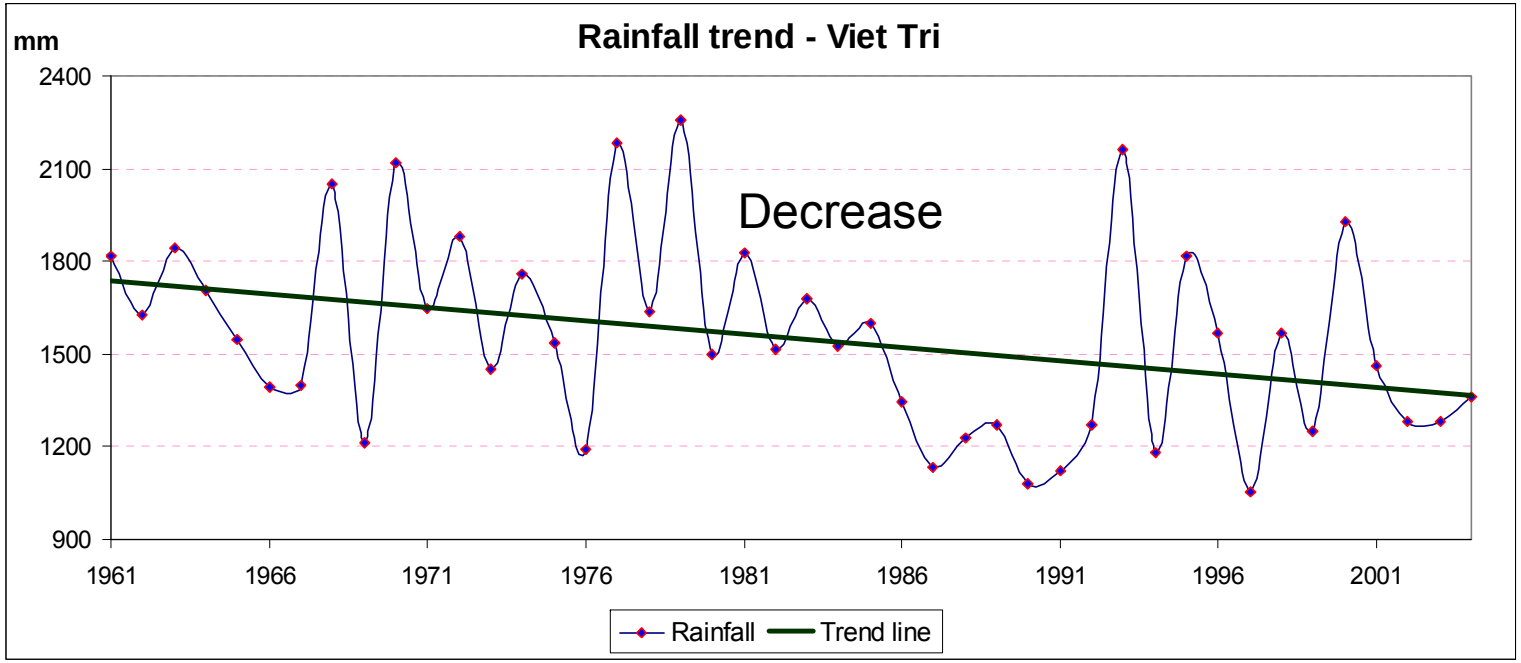
Results

- Temperature



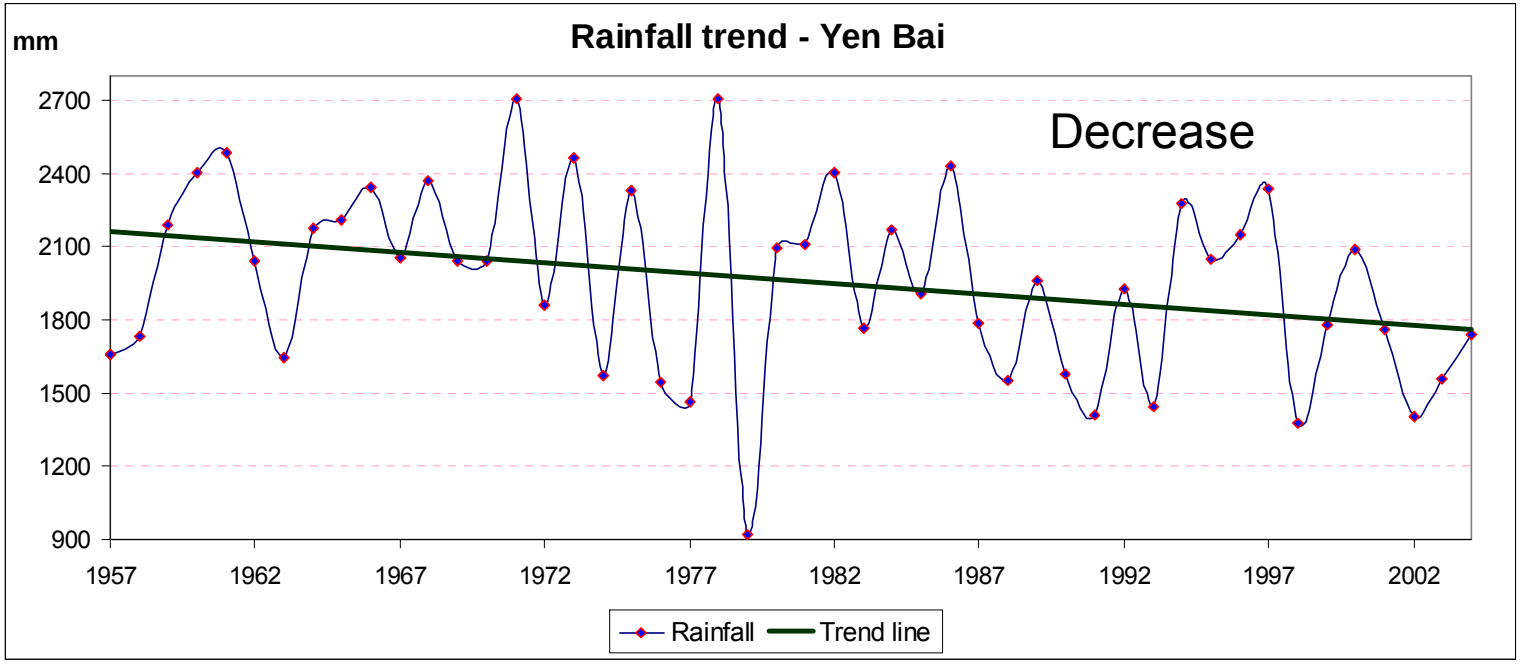
Results

- Rainfall
  - Linear regression



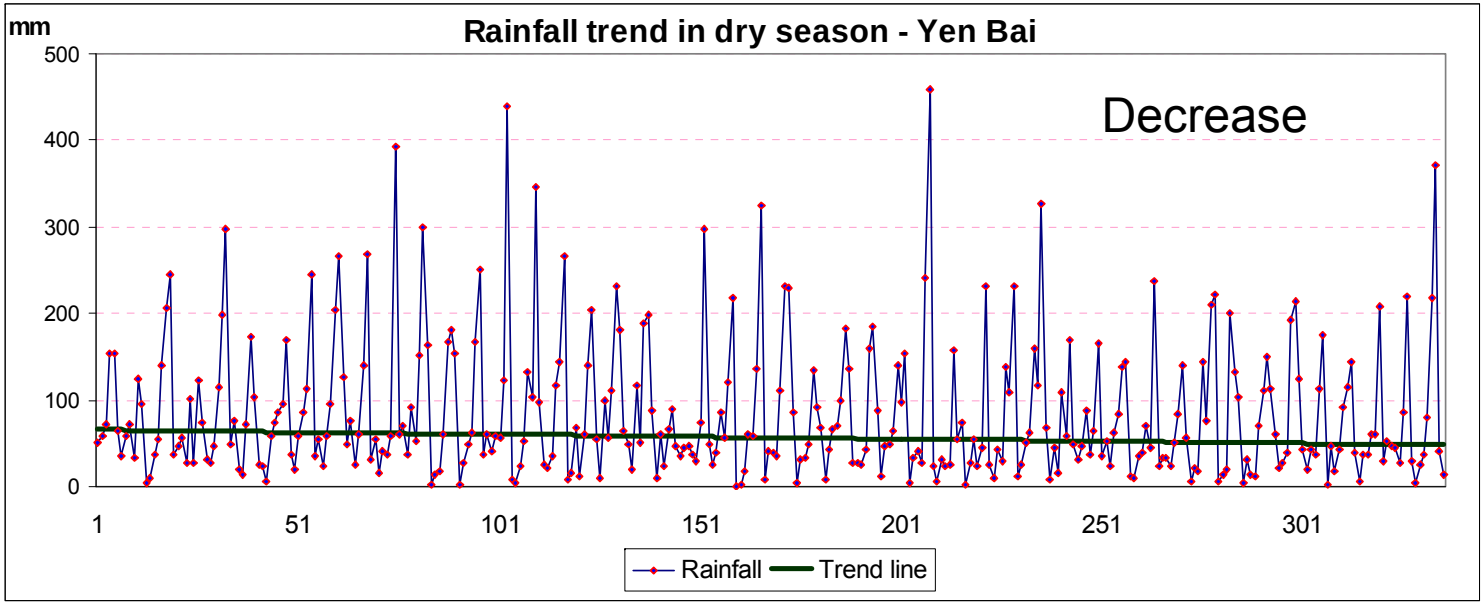
Results

- Rainfall
  - Linear regression



Results

- Rainfall
  - Mann-Kendall: similar results to LR
  - Seasonal Mann-Kendall



Results

- Rainfall
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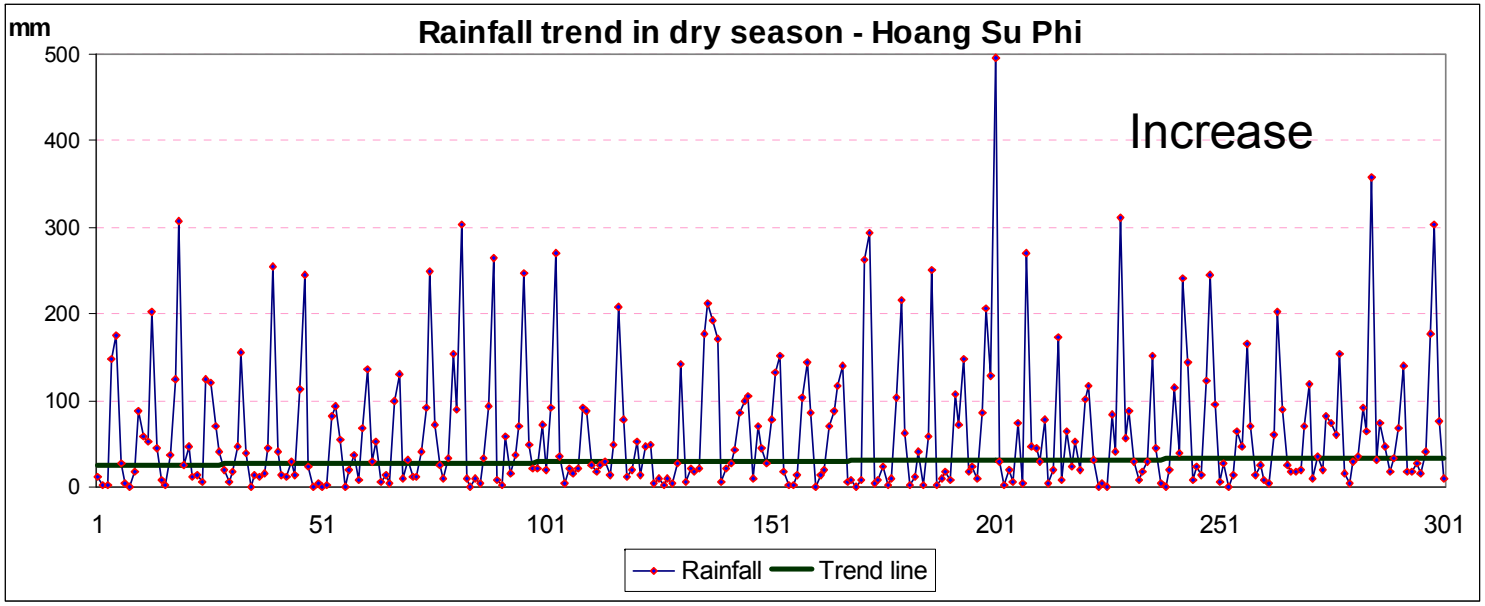
  - Seasonal Mann-Kendall



Results

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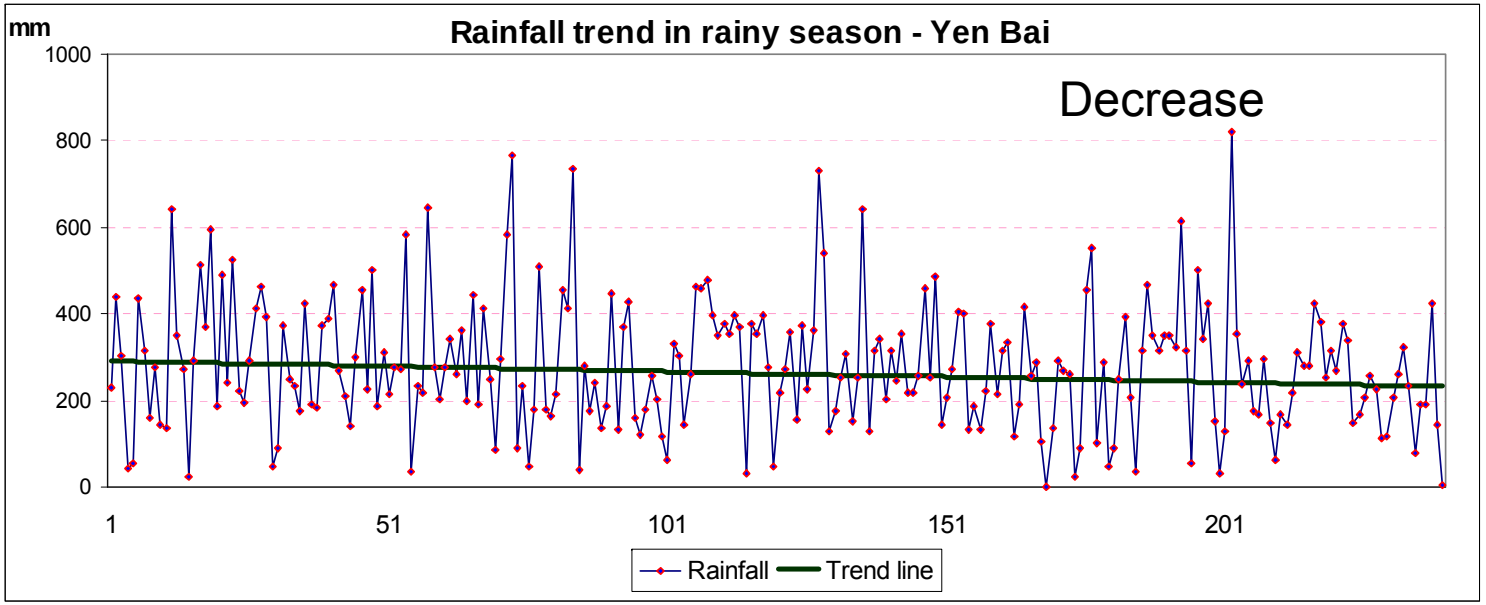
  - Seasonal Mann-Kendall



Results

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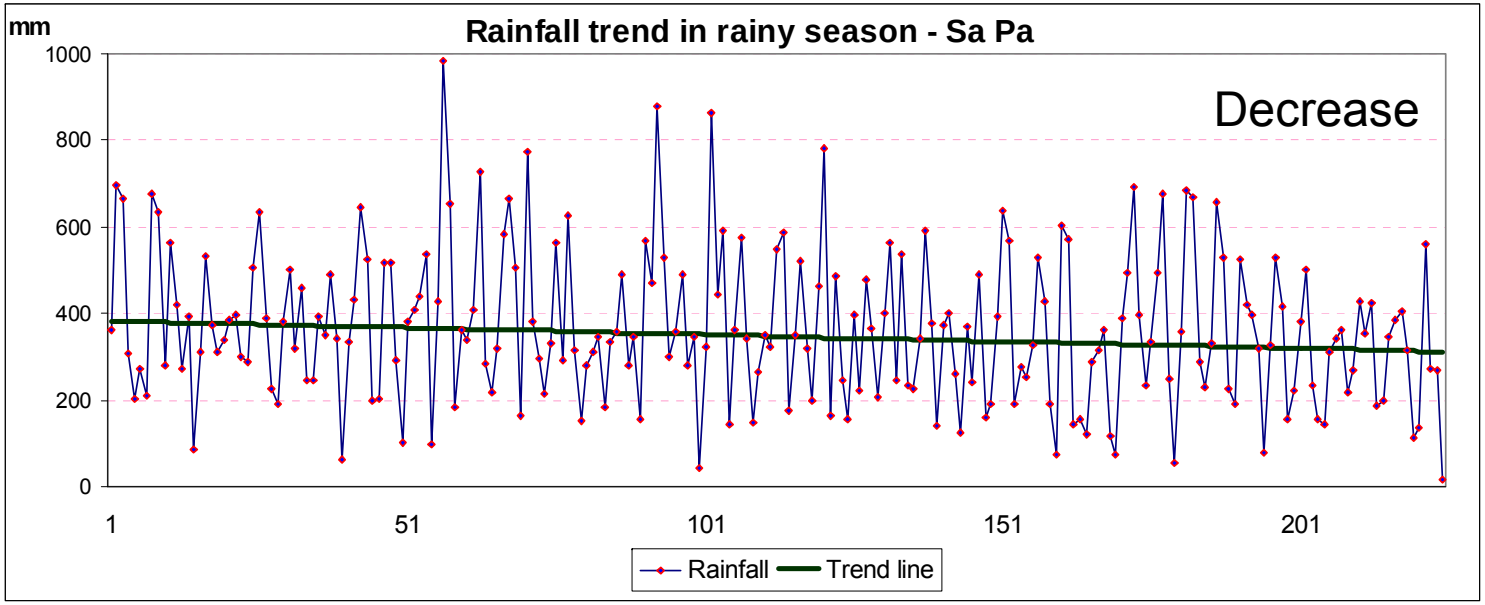
  - Seasonal Mann-Kendall



Results

- Rainfall

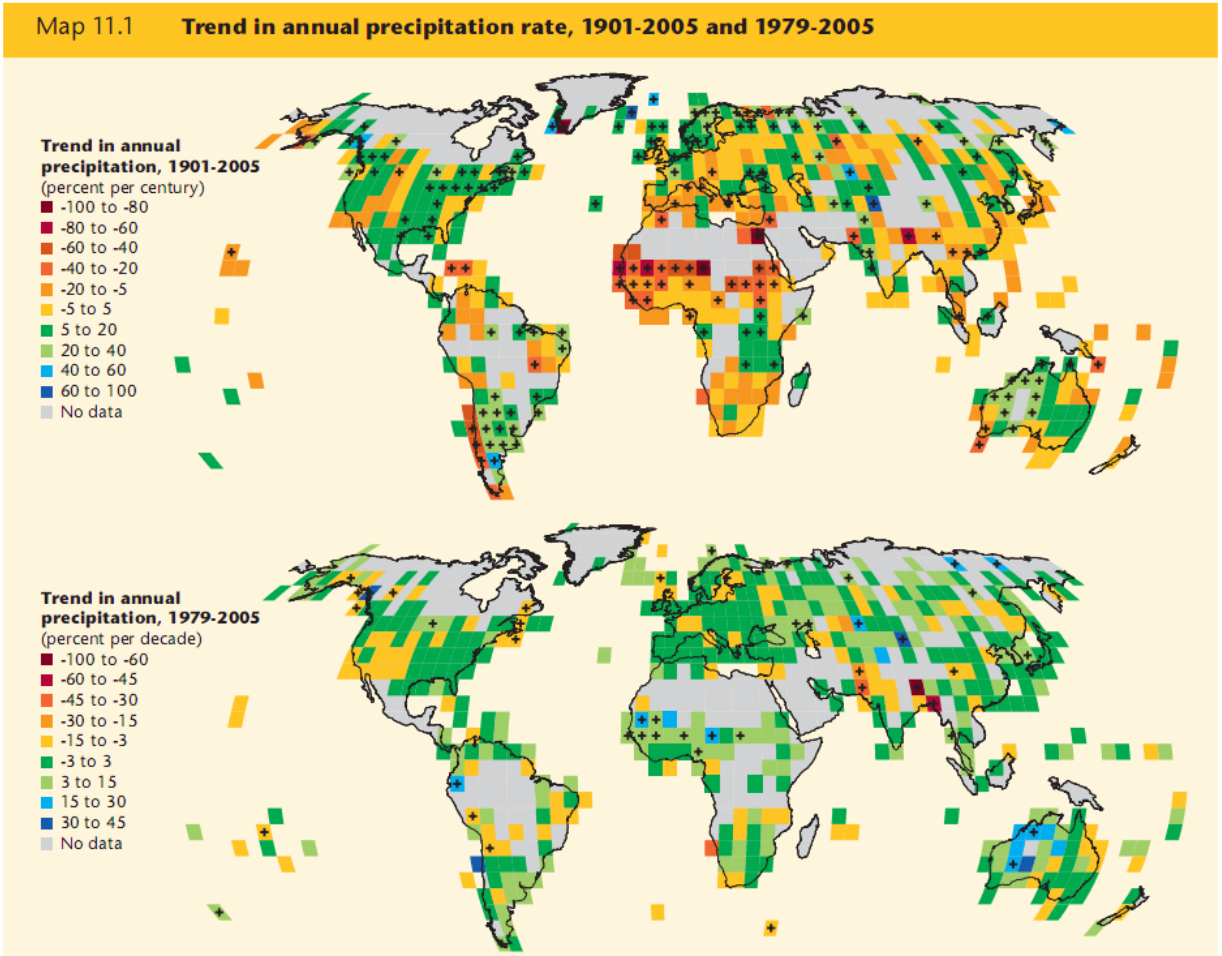
Trend analysis for rainfall

No	Station	Linear regression			Mann-Kendall				Seasonal Mann-Kendall							
									Dry season				Rainy season			
		Sigma	S	Trend	S	Z	P	Trend	S	Z	P	Trend	S	Z	P	Trend
1	Hoa Binh	3.512	-0.643	Stable	129	0.328	0.7426	No trend	360	1.206	0.2278	No trend	-231	-0.914	0.3606	Stable
2	Lai Chau	3.002	-0.087	Stable	-42	-0.105	0.9162	Stable	143	0.477	0.6333	No trend	-185	-0.731	0.4645	Stable
3	Moc Chau	3.246	-1.156	Stable	-297	-0.864	0.3874	Stable	-54	-0.203	0.8181	No trend	-239	-1.077	0.2817	Stable
4	Muong Te	4.011	-1.7	Probably Decreasing	-112	-0.324	0.7458	Stable	267	1.017	0.3091	No trend	-379	-1.71	0.0873	Decreasing
5	Son La	2.484	-0.325	Stable	-111	-0.322	0.7473	Stable	306	1.167	0.2432	Stable	-435	-1.963	0.0496	Decreasing
6	Bac Quang	10.589	-0.052	Stable	-73	-0.218	0.8278	Stable	-121	-0.475	0.635	Stable	48	0.22	0.8259	No trend
7	Ha Giang	3.515	-0.539	Stable	-85	-0.209	0.8344	Stable	205	0.665	0.5062	No trend	-290	-1.114	0.2652	Stable
8	Ham Yen	3.203	-1.456	Stable	-311	-0.905	0.3654	Stable	129	0.489	0.6246	No trend	-440	-1.986	0.048	Decreasing
9	Hoang Su Phi	2.954	-1.446	Stable	24	0.069	0.9446	No trend	498	1.966	0.0493	Increase	-474	-2.214	0.0268	Decreasing
10	Tuyen Quang	2.904	-0.262	Stable	-131	-0.381	0.7035	Stable	177	0.673	0.501	No trend	-308	-1.398	0.1621	Stable
11	Viet Tri	4.425	-2.275	Decreasing	-832	-2.427	0.0152	Decreasing	-72	-0.271	0.786	Stable	-760	-3.434	0.0006	Decreasing
12	Bac Ha	2.613	-1.535	Stable	-384	-0.983	0.3257	Stable	291	0.974	0.3299	No trend	-675	-2.679	0.0074	Decreasing
13	Sa Pa	4.685	-1.7	Probably Decreasing	-370	-1.051	0.2935	Stable	168	0.62	0.535	No trend	-538	-2.38	0.0173	Decreasing
14	Yen Bai	3.882	-2.214	Decreasing	-1410	-3.634	0.0003	Decreasing	-912	-3.061	0.0022	Decrease	-498	-2	0.0455	Decreasing

Results

- Rainfall

Map 11.1 **Trend in annual precipitation rate, 1901-2005 and 1979-2005**

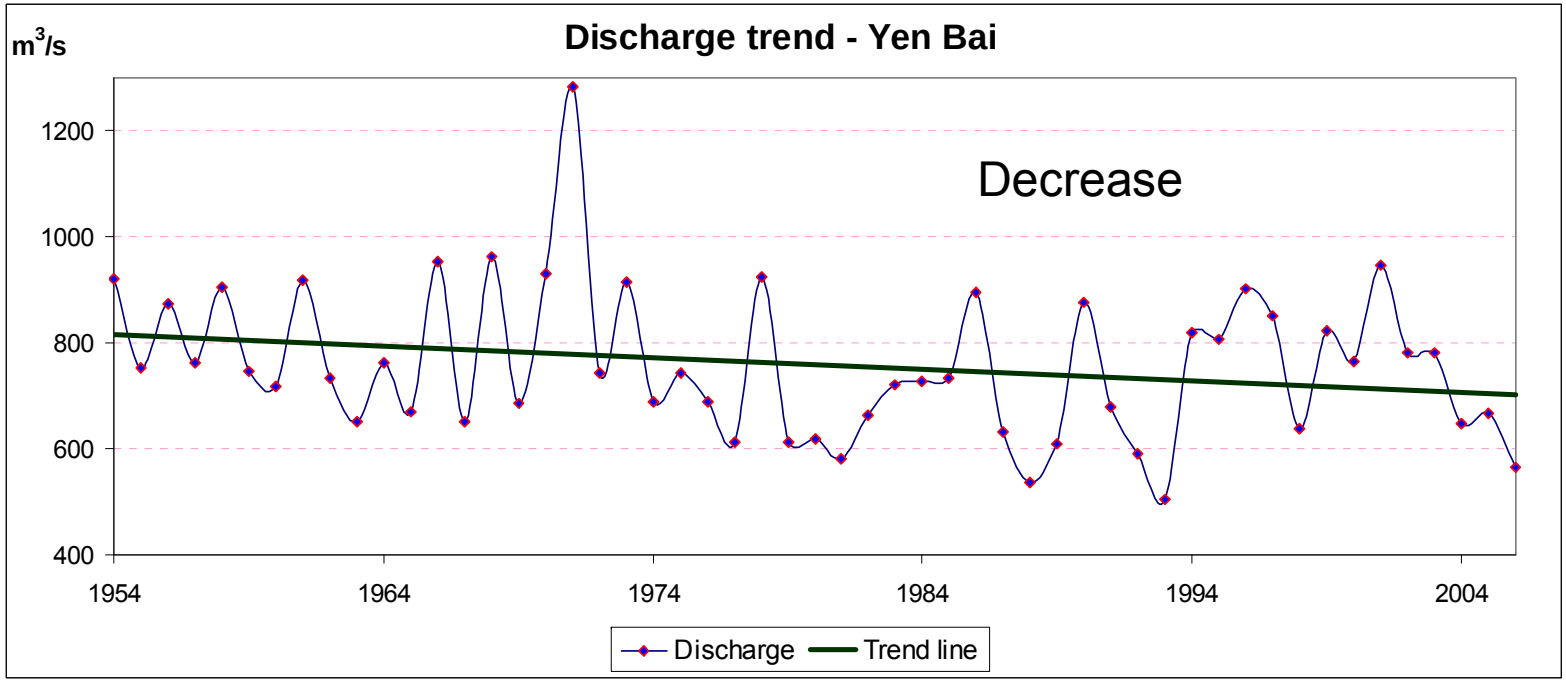


+ is a trend that is statistically significant at the 5% level.

Source: IPCC 2007, chapter 3.

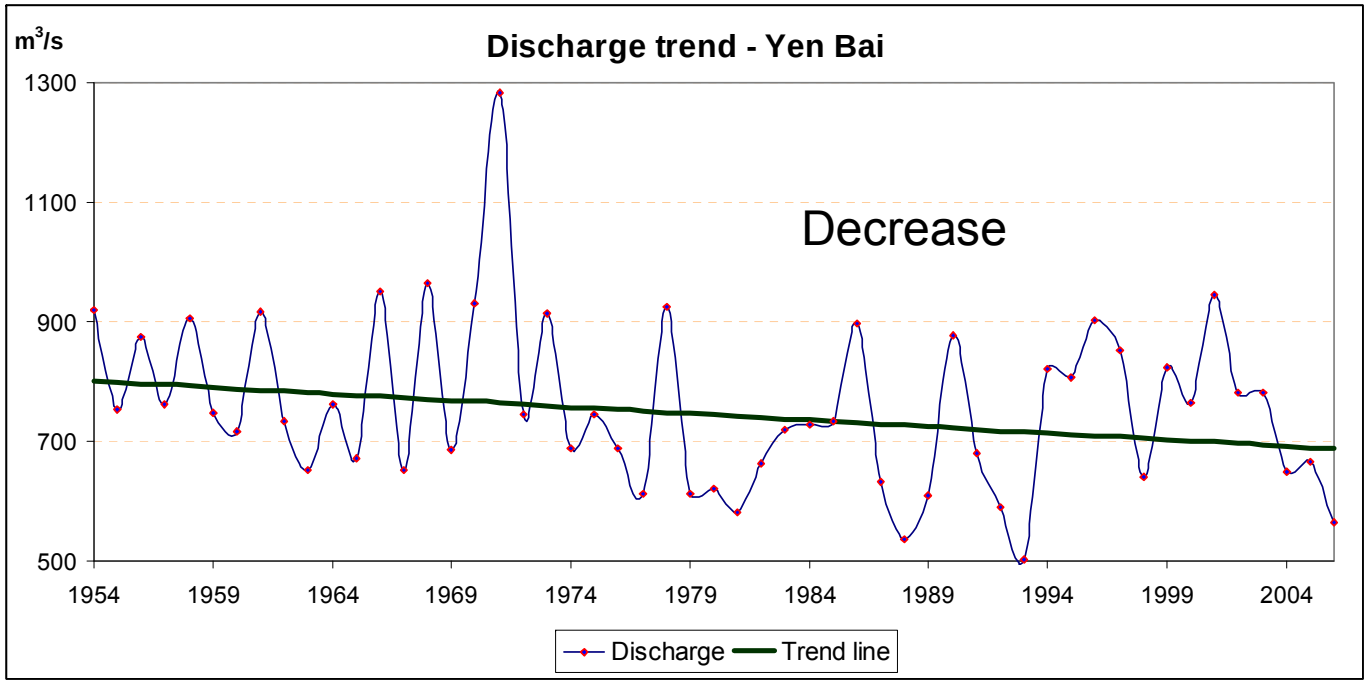
Results

- Streamflows
  - Linear regression and Mann-Kendall test:



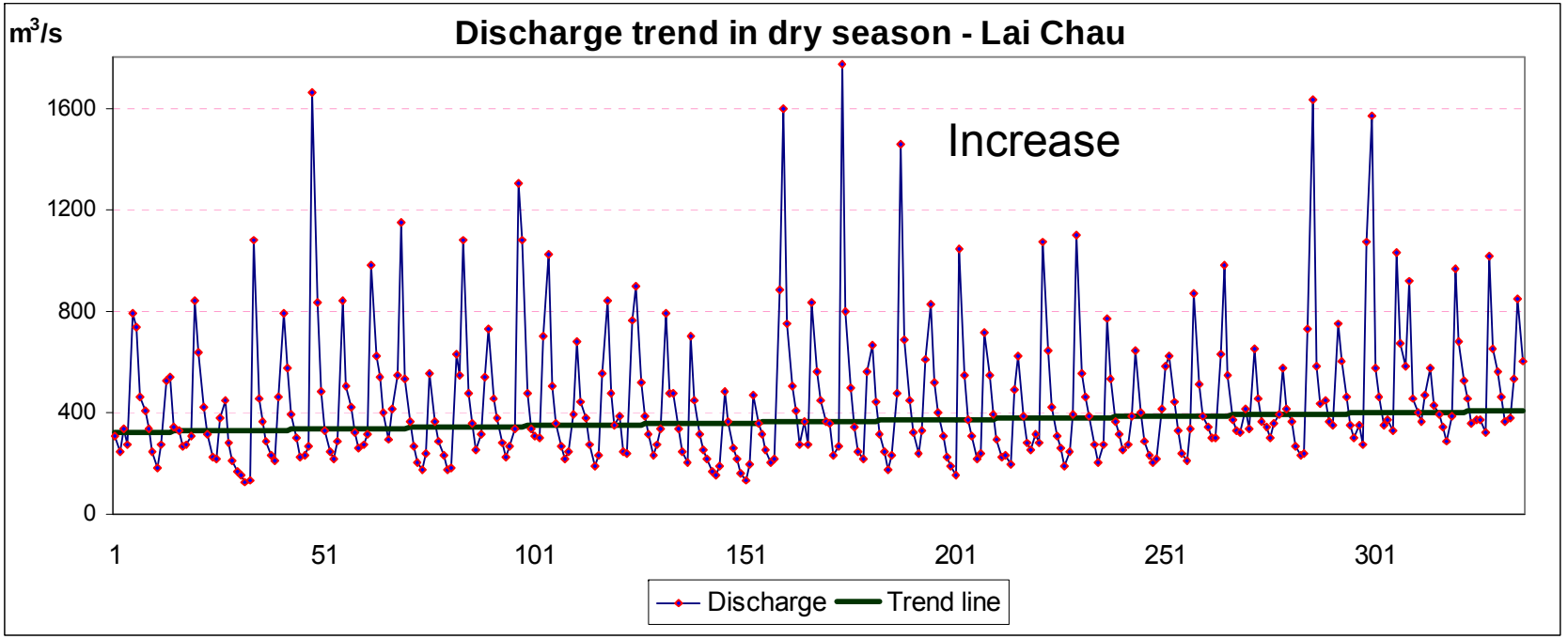
Results

- Streamflows
  - Linear regression and Mann-Kendall test:



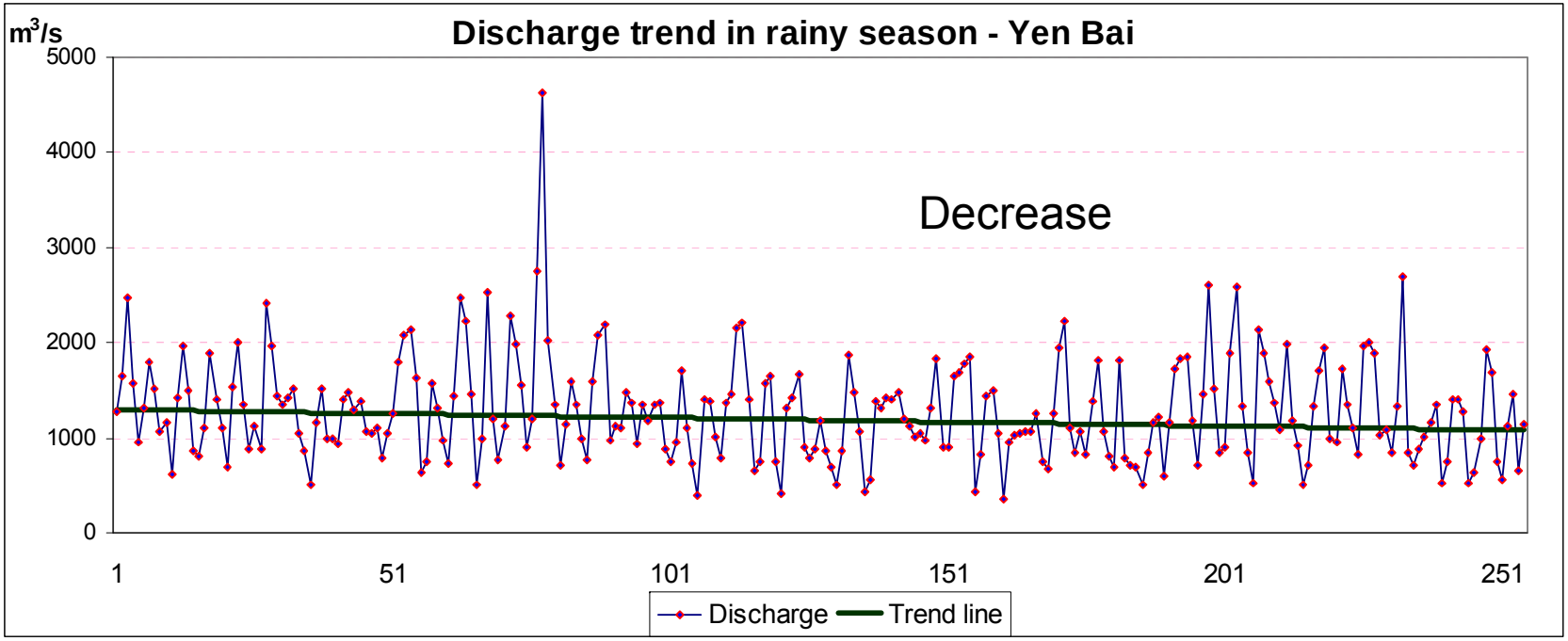
Results

- Streamflows
  - Seasonal Mann-Kendall test:



Results

- Streamflows
  - Seasonal Mann-Kendall test:



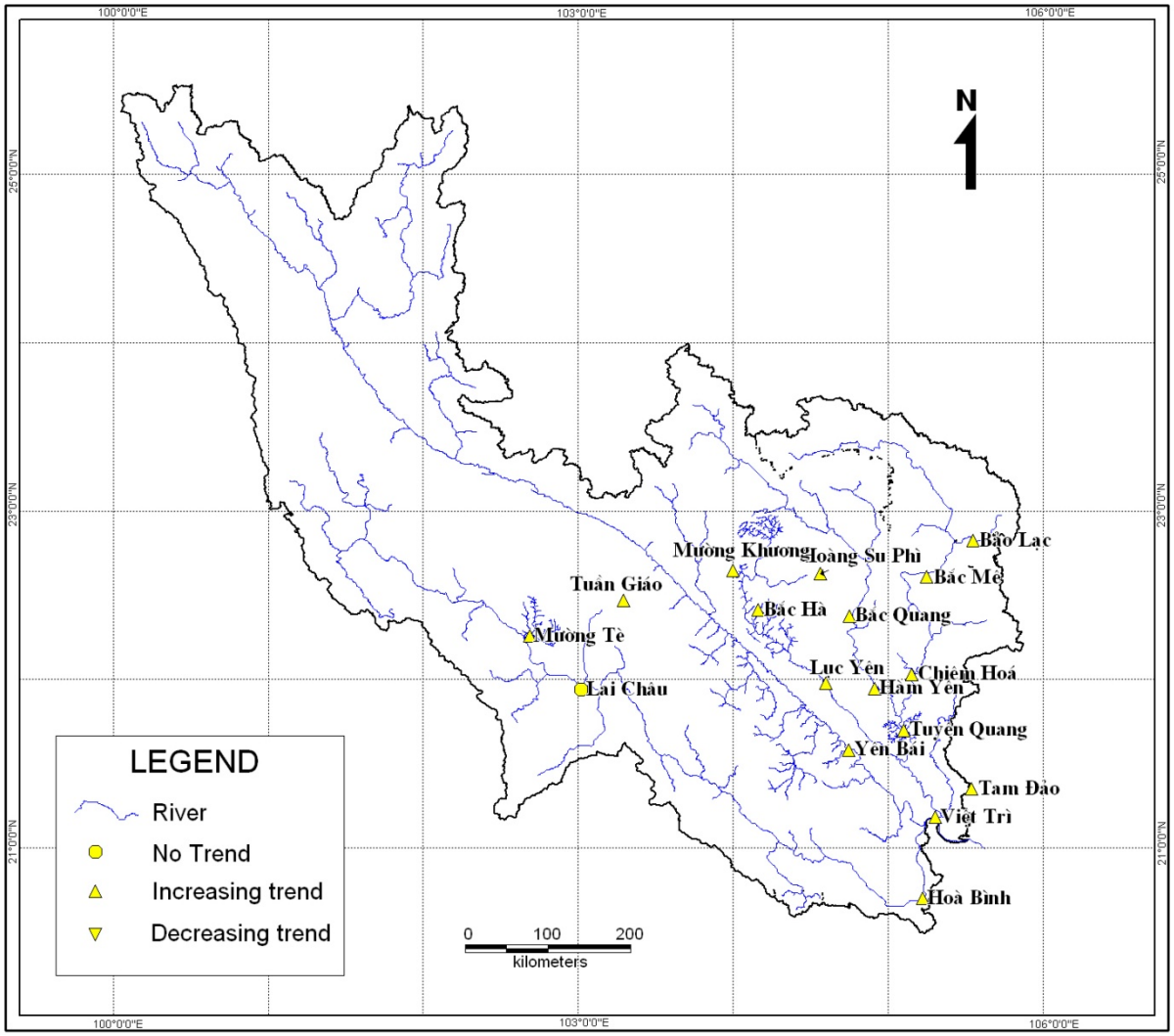
Results

- Streamflow

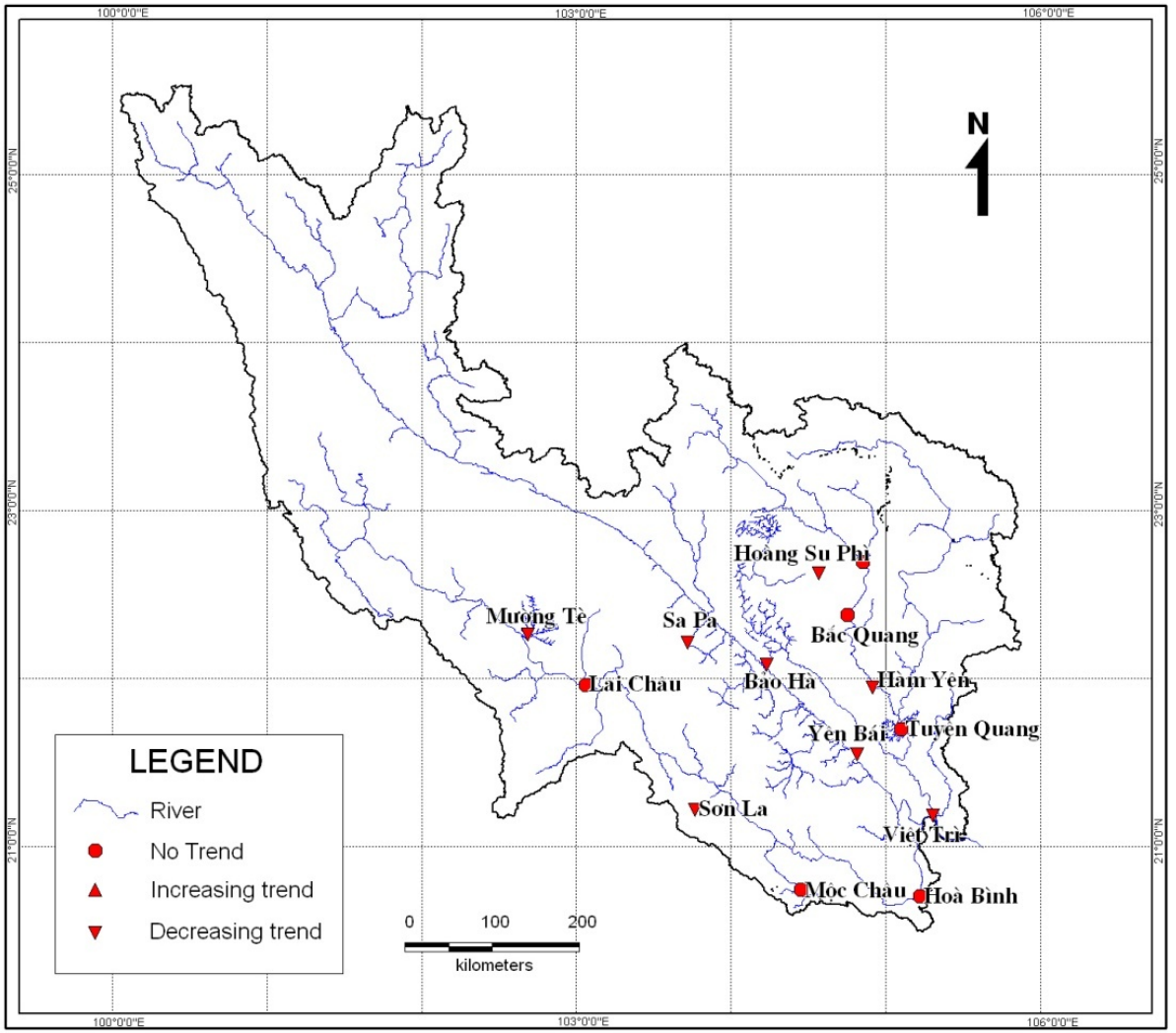
Trend analysis for streamflow

No	Station	Seasonal Mann-Kendall							
		Dry season				Rainy season			
		S	Z	P	Trend	S	Z	P	Trend
1	Chiem Hoa	612	2.187	0.0288	Increasing	208	0.877	0.3807	No trend
2	Ghenh Ga	506	1.697	0.0898	Increasing	405	1.606	0.1083	No trend
3	Lai Chau	1283	4.307	0	Increasing	268	1.061	0.2885	No trend
4	Ta Bu	238	0.848	0.3963	No trend	165	0.695	0.4873	No trend
5	Yen Bai	-375	-1.219	0.223	Stable	-600	-2.309	0.059	Decreasing

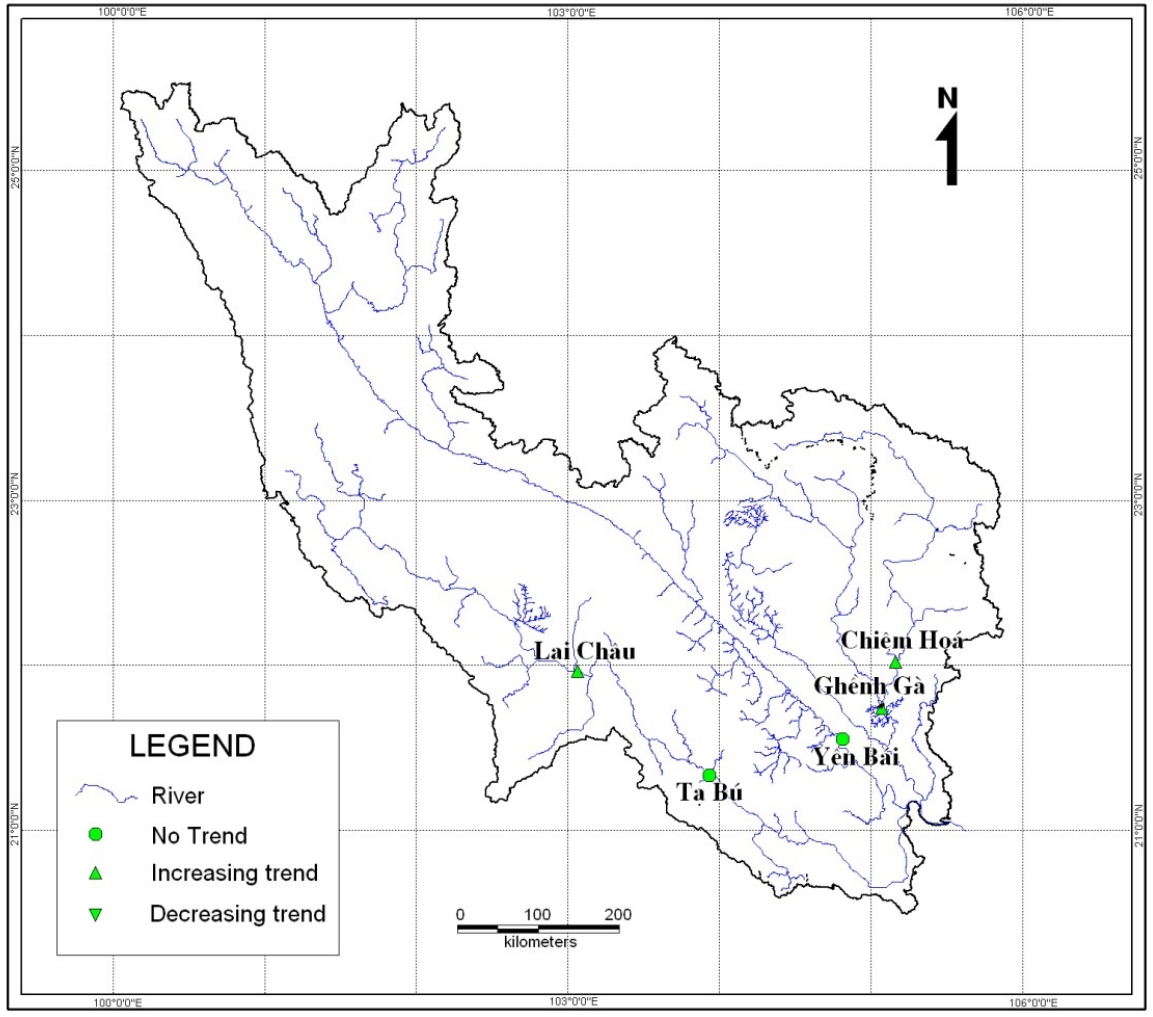
Spatial distribution of annual temperature trends using MK



Spatial distribution of monthly rainfall trends in rainy season using MK



Spatial distribution of monthly streamflow trends in drought season using MK



Conclusions

- significant increase of temperature;
- little change is observed in annual data, but significant changes are observed on a monthly basis;
- increases in low flow and decreases in rainfall and mean annual flow;
- changes in rainfall can only partly explain the observed trends in streamflow.

Outlooks

- serial correlation and cross correlation (trend-free pre-whitening, bootstrap, permutation…);
- human interventation: land use change, water supply extraction, deforestation, reservoir regulation…;
- extreme event: peak discharge, mininum discharge, timing of flood …;

THANK YOU