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Hydrological change versus climate change

Long-term properties of annual maximum daily river discharge worldwide

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1. Abstract

We use a database of annual maximum daily discharge time series (World Catalogue of Maximum Observed Floods, IAHS Press, 2003) and extract those with length greater than 50 years. We analyse extreme floods at several stations worldwide focusing on the long-term properties of the time series including trends and persistence (else known as Hurst-Kolmogorov dynamics), which characterizes the temporal streamflow variability across several time scales. The analysis allows drawing conclusions, which have some importance, given the ongoing and intensifying discussions about worsening of climate and amplification of extreme phenomena.

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2. Motivation

Floods are a threat not only for technical works, but also for human lives, since they cause more deaths than any other natural disaster. According to common belief which is supported by several publications (e.g. Milly et al., 2002; CRED, 2004), the severity, frequency and consequences from floods have been increased in recent years. These perceptions have motivated us to examine whether this argument is confirmed by observed data of annual maximum daily discharge from several stations worldwide.

Long discharge records in relatively intact river basins are essential for reliable and representative results. Hence a large and consistent global database of flood events is required as a basis for our research.

Statistical indices derived from these data can then be used to assess whether there is a general increasing tendency worldwide, especially considering the last climate period (after 1970) when the effects of global warming are believed to be apparent.

3. Data

We created a database of annual maximum daily discharge time series based on the “World Catalogue of Maximum Observed Floods” (Herschy, 2003). The maximum floods were observed at regular hydrometric stations or at sites for which the a posteriori estimation of flood discharge was possible or where the maximum water level was observed.

Because of strong climate variability, records of less than 30 years are almost certainly too short for detection of systematic trends. A minimum of 50 years of records is necessary for trend detection and in the case of strong natural variability even longer time series may be essential (Kundzewicz & Robson, 2004). Therefore, from the stations provided by the World Catalogue, we chose the ones with at least 50 annual maximum values (excluding missing ones). In total, 119 stations fulfil this criterion, all of which were used in the analyses.

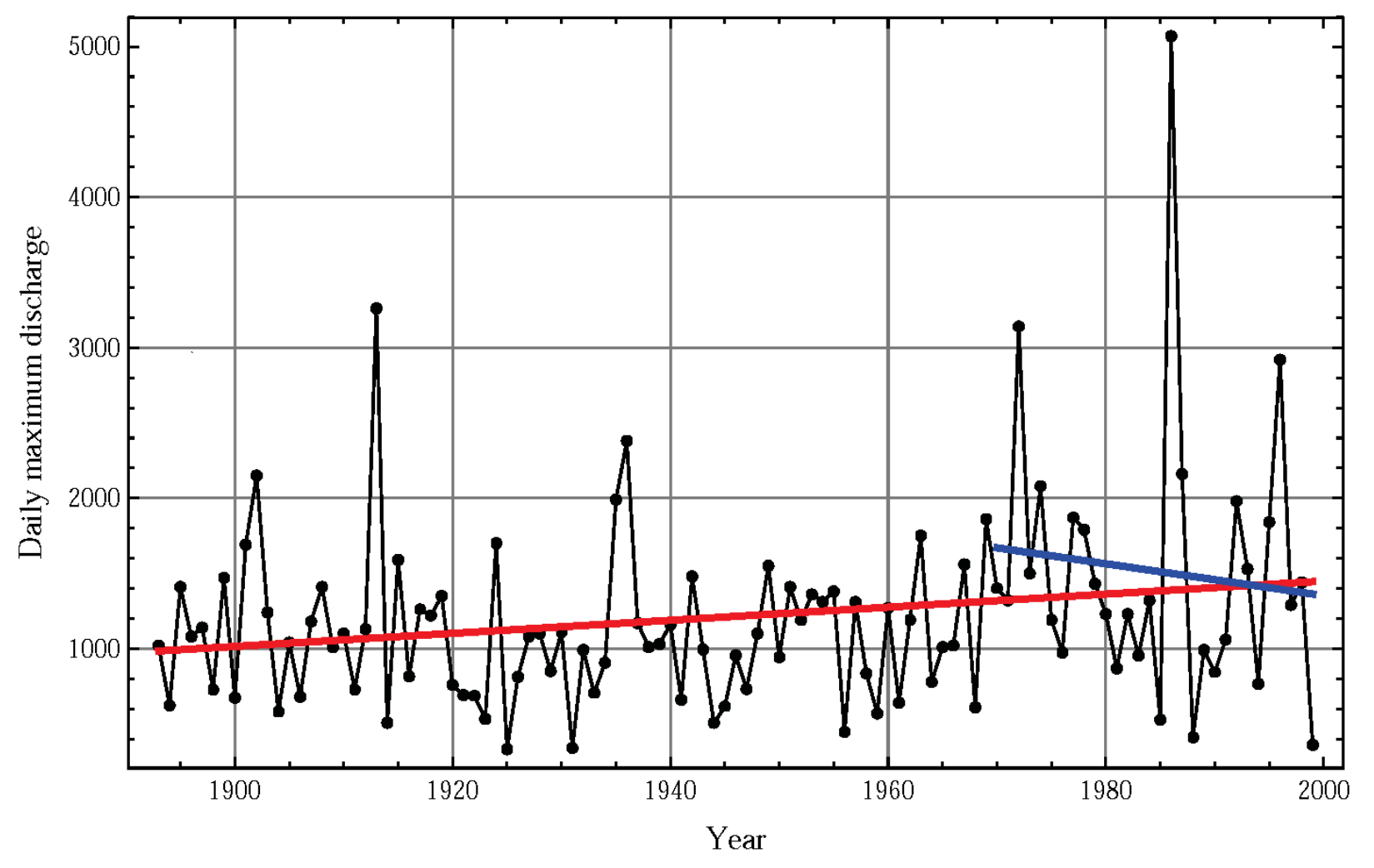
Table 1 Geographical distribution of the stations used in the analysis.

	Number of non-missing values								
	50-60	61-70	71-80	81-90	91-100	101-110	111-120	>121	Total number of stations
Europe	8	10	14	9	4		3	3	51
Africa	1		5	2					8
Asia	6	3	2						11
Oceania			1						1
North America	8	9	12	9	6	2	1		47
South America	1								1
Total	24	22	34	20	10	2	4	3	119

4. Statistical indices (1)

Firstly, we examine the trends (estimated by regression) for the total length of the time series as well as for the period after 1970.

The trends are highly dependant on the standard deviation (s) and the autocorrelation structure of each time series (Papalexiou and Zarkadoulas, 2009), and consequently they cannot be directly compared. The comparison is based on a normalized expression, where the trend is divided by the standard deviation of each corresponding period.

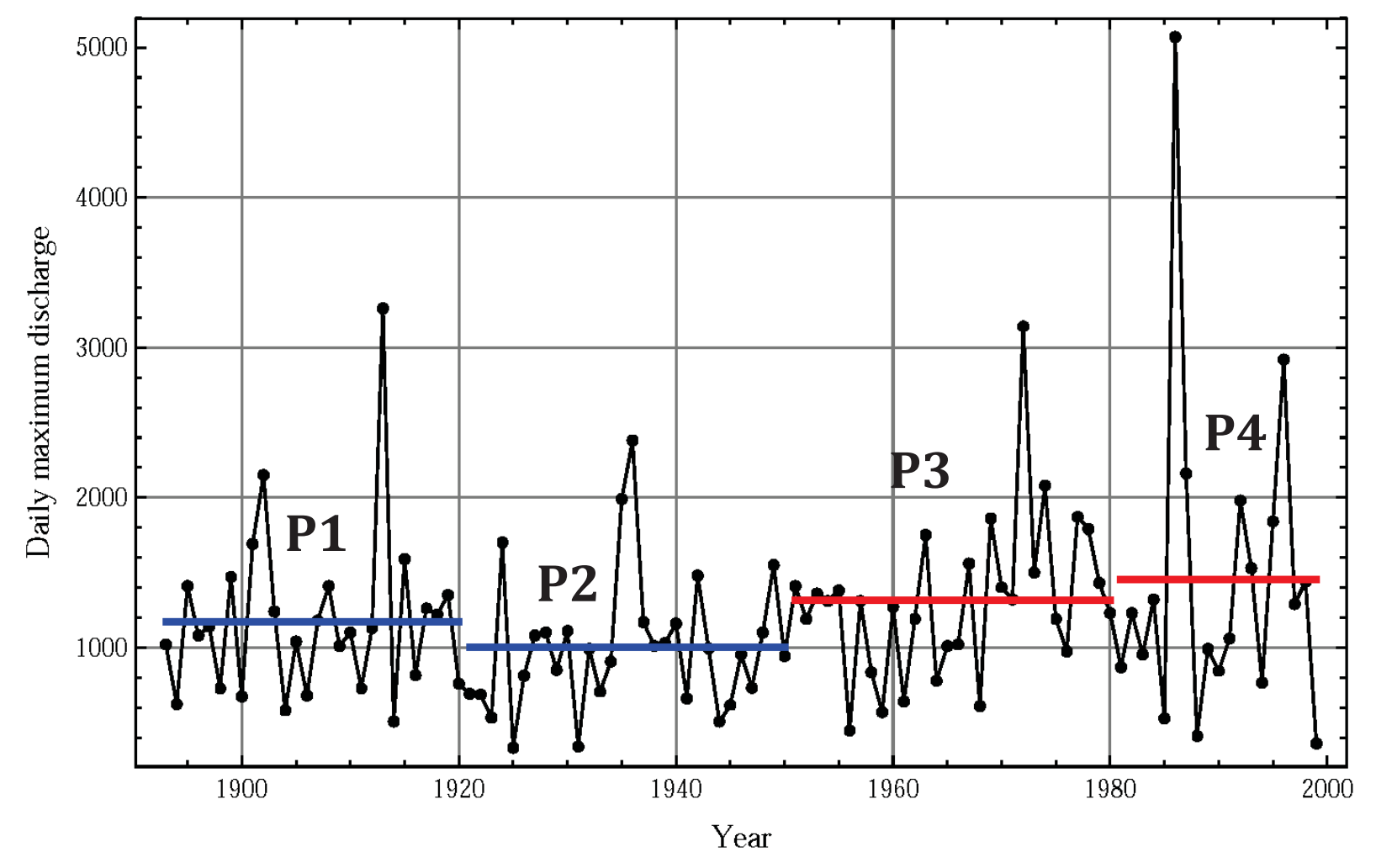


Time series from the station at James River at Buchanan ,Virginia, U.S.A, and the trends for the total length of years and for the period after 1970 (units m^3/s)

5. Statistical indices (2)

We also partitioned the total length of each time series into 30-year periods, (P1: 1891-1920, P2: 1921- 50, P3: 1951-80, P4: 1981-2010), since a period of 30 years is commonly considered as a typical basis in climate research.

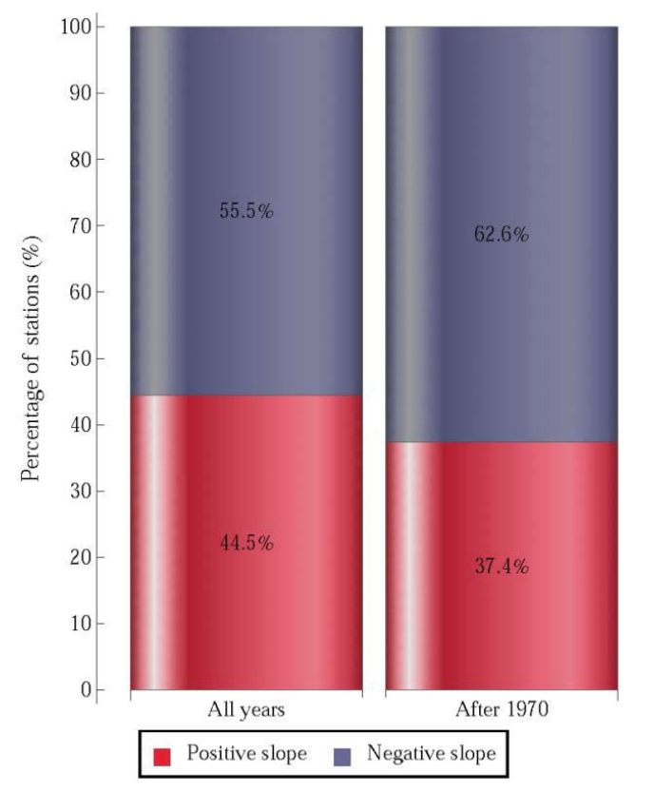
The comparison of each pair of consecutive periods is based on two statistical indices: the mean value and the standard deviation. More specifically, we estimated the percent change of the indices between two consecutive 30-year periods, excluding the periods with more than 15 missing values.

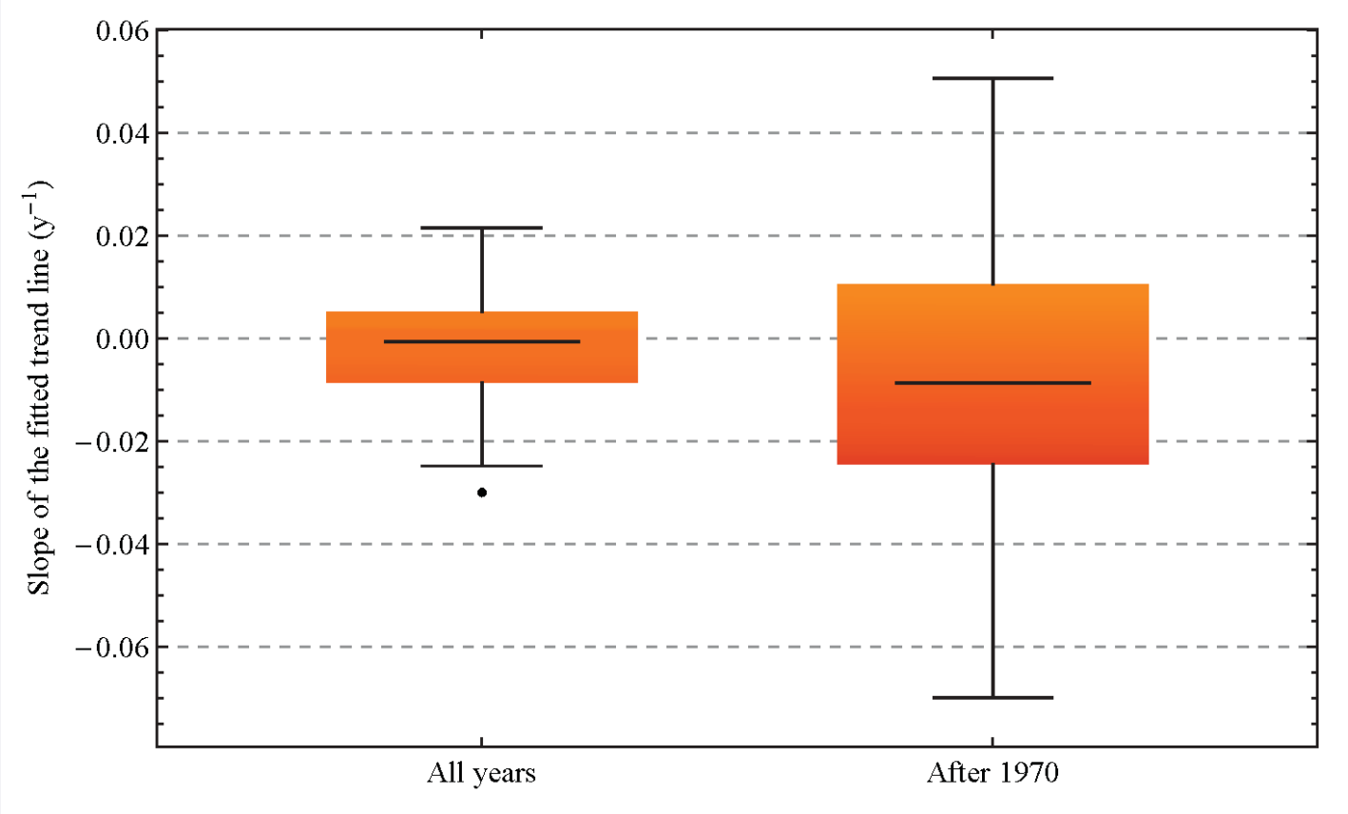


Time series from the station at James River at Buchanan. Virginia, U.S.A, and the mean value for each 30-year period (units m^3/s).

6. Results of trend analysis

The chart on the right shows the percentage of the positive and negative slopes of the trend lines, for all years and for the period after 1970 respectively. Contrary to what is believed, the percentage of increasing trends is lower than that of decreasing trends, particularly in the most recent period.

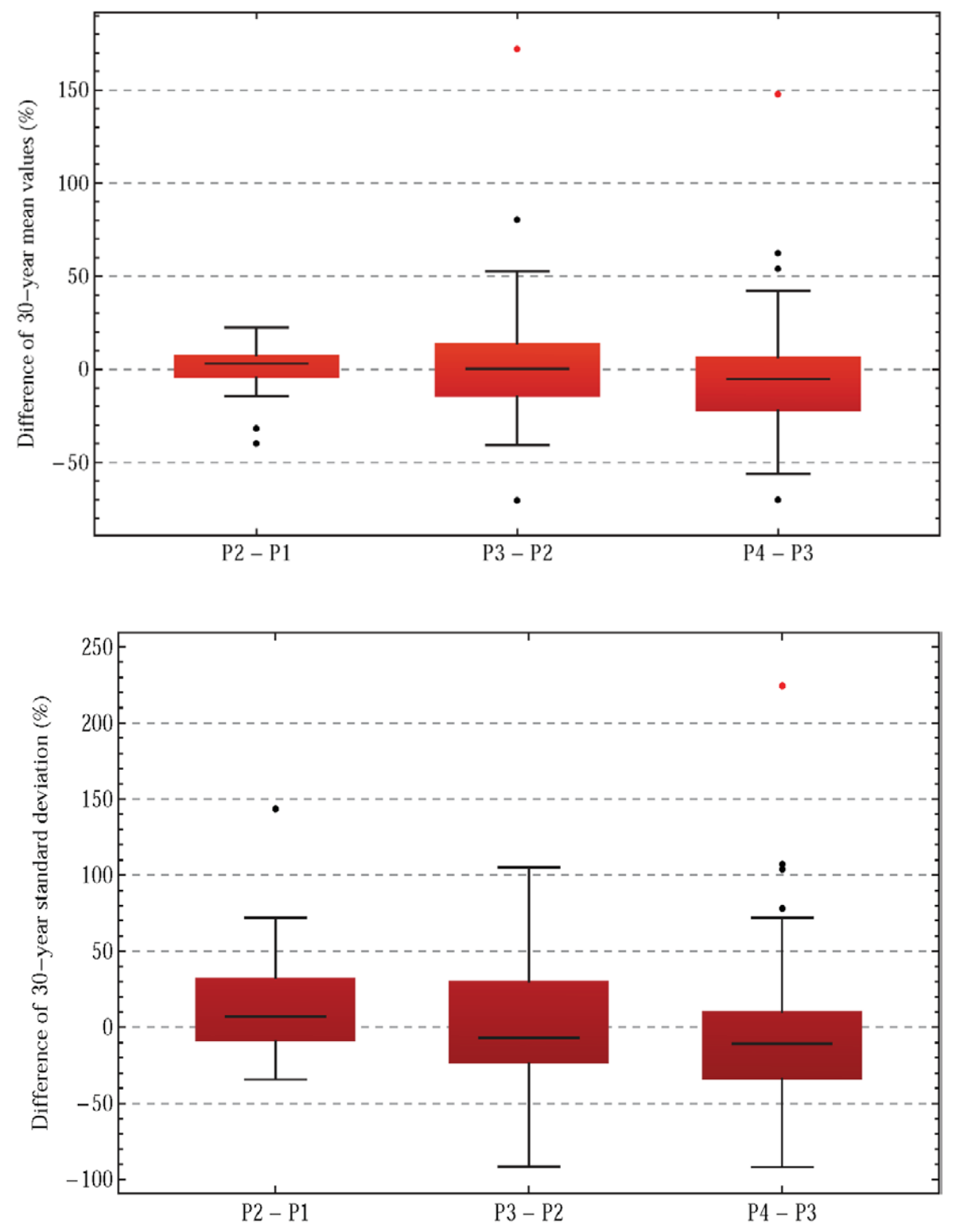




From the box plots of slopes, we observe the following:

- The quartile interval for the total length is quite short as the majority of time series have a small trend line slope.
- The range of values in the period after 1970 is larger than the one of the previous box plot. It is observed that the median of the trend lines is negative.

7. Results for climatic means and standard deviations



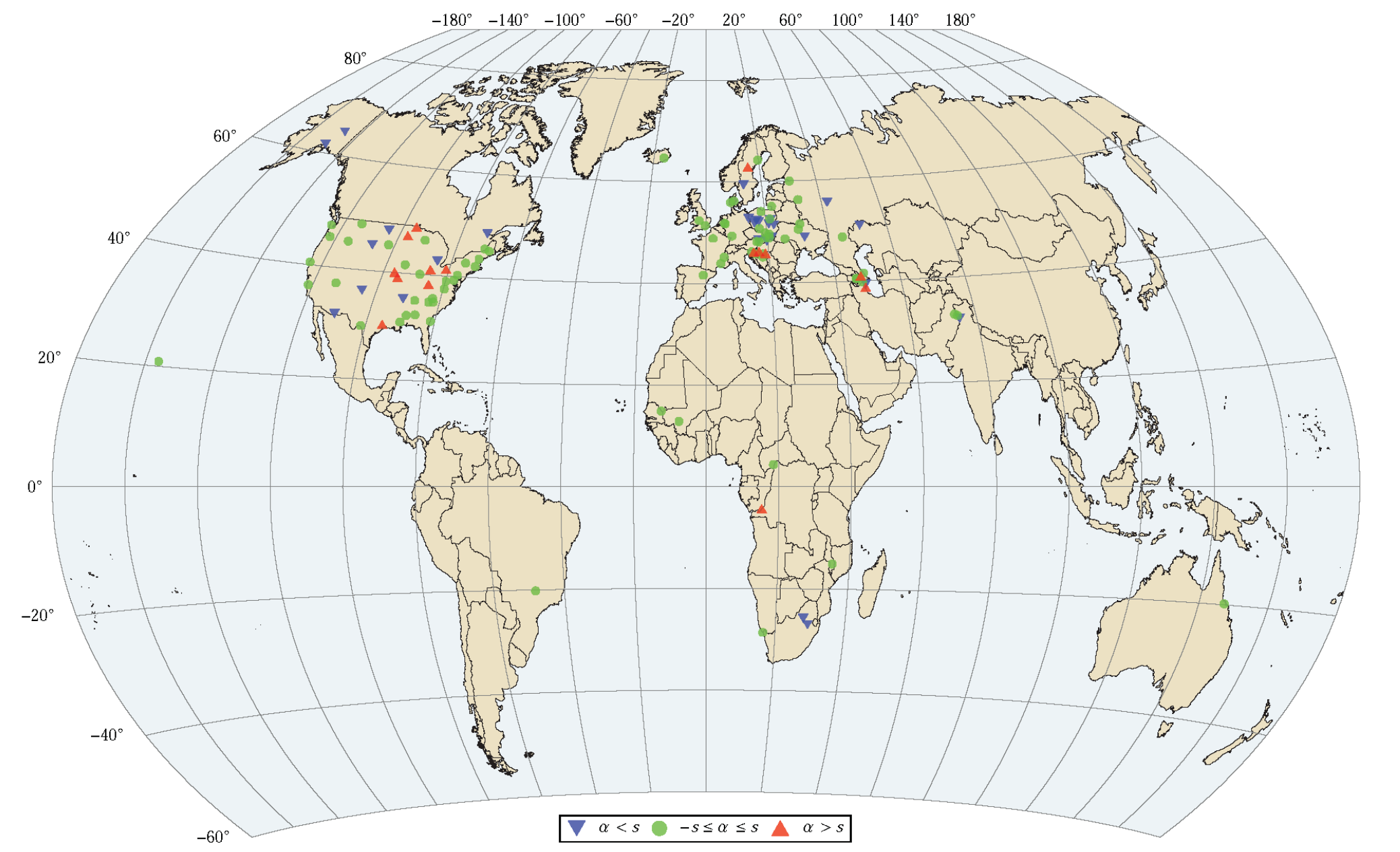
P2-P1: There is no apparent change between the two periods. (Note that only a few stations had available data for both these periods, which is reflected in small size of the box plot).

P3-P2: Percentages of decreasing and increasing values are almost equal.

P4-P3: Most of the mean values and standard deviations of the river discharges are decreasing.

There is a decreasing trend in both statistical indices, which can be noticed from the decreasing values of P4-P3 compared to P3-P2.

8. Time series trends of all years

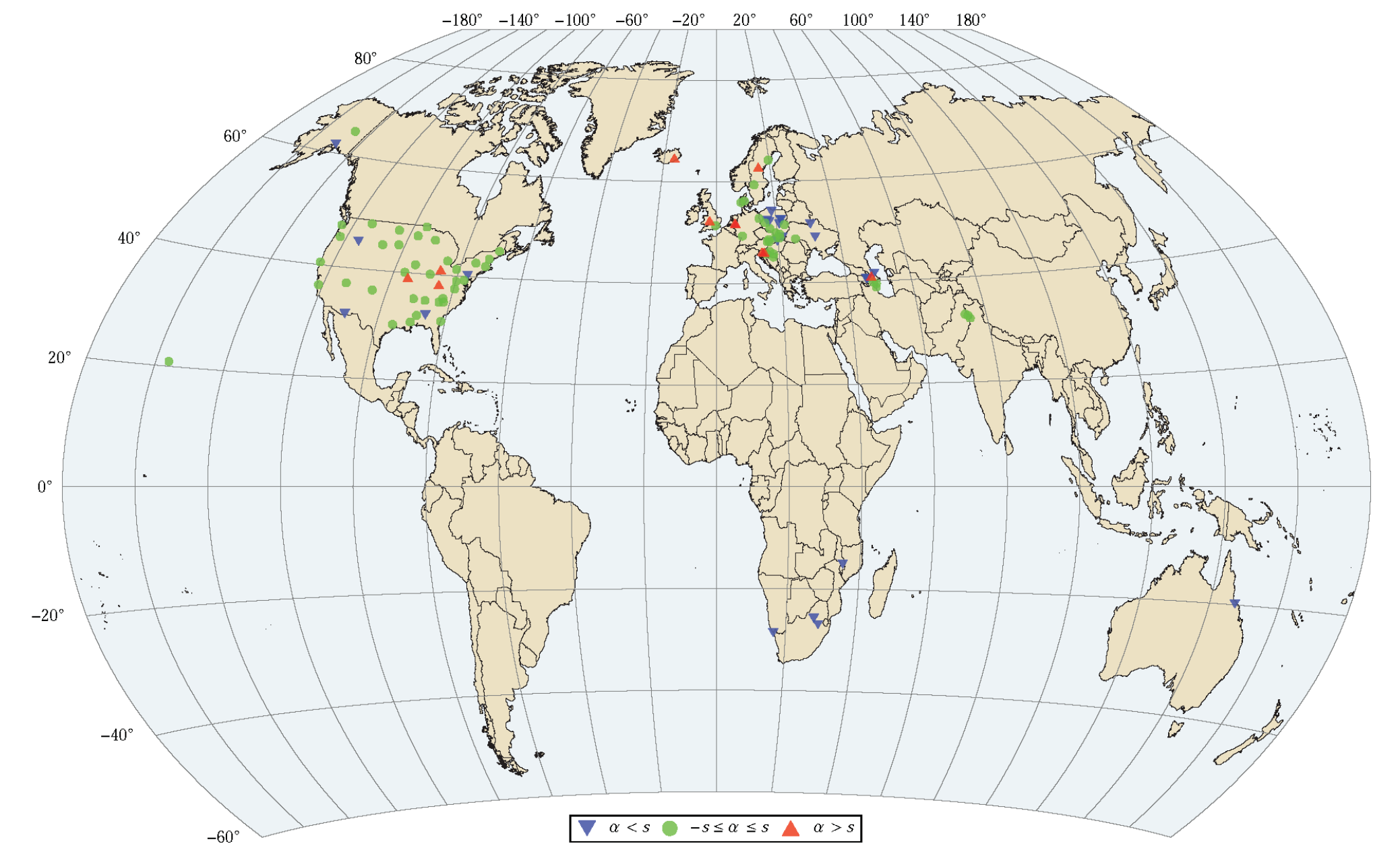


The blue triangles depict decreasing trends	(28/119 stations)
The green circles depict small changes within (-s, s)	(76/119 stations)
The red triangles depict increasing trends	(15/119 stations)

$s = 0.0094$

The figure depicts the station locations and the corresponding trends. All have annual maximum daily discharge time series with at least 50 non-missing values. The stations are a subset of the World Catalogue of Maximum Observed Floods database, which contains maximum discharges that are distributed across all continents.

9. Time series trends of the last period (after 1970)

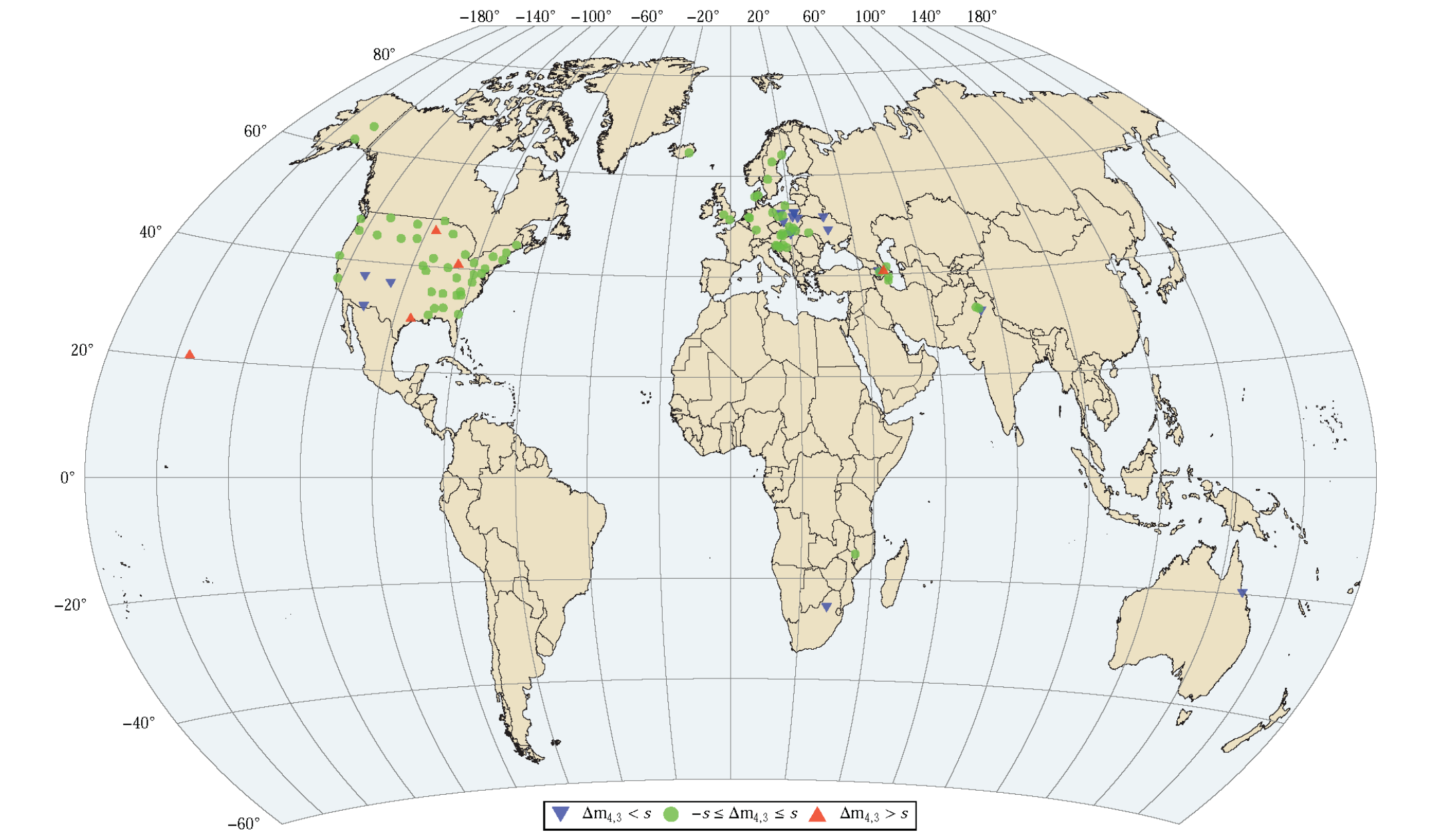


The blue triangles depict decreasing trends	(23/98 stations)
The green circles depict small changes within (-s, s)	(64/98 stations)
The red triangles depict increasing trends	(11 /98 stations)

$s = 0.0260$

The figure depicts the station locations and the corresponding trends of the last period (after 1970). Only stations with 15 or more non-missing values in that period are plotted. Those with increasing trends are fewer than 1/2 of those with decreasing trends.

10. Mean value difference between the last 2 periods, Δm_{43}



The blue triangles depict decreasing trends	(17/94 stations)
The green circles depict small changes within (-s, s)	(72/94 stations)
The red triangles depict increasing trends	(5 /94 stations)

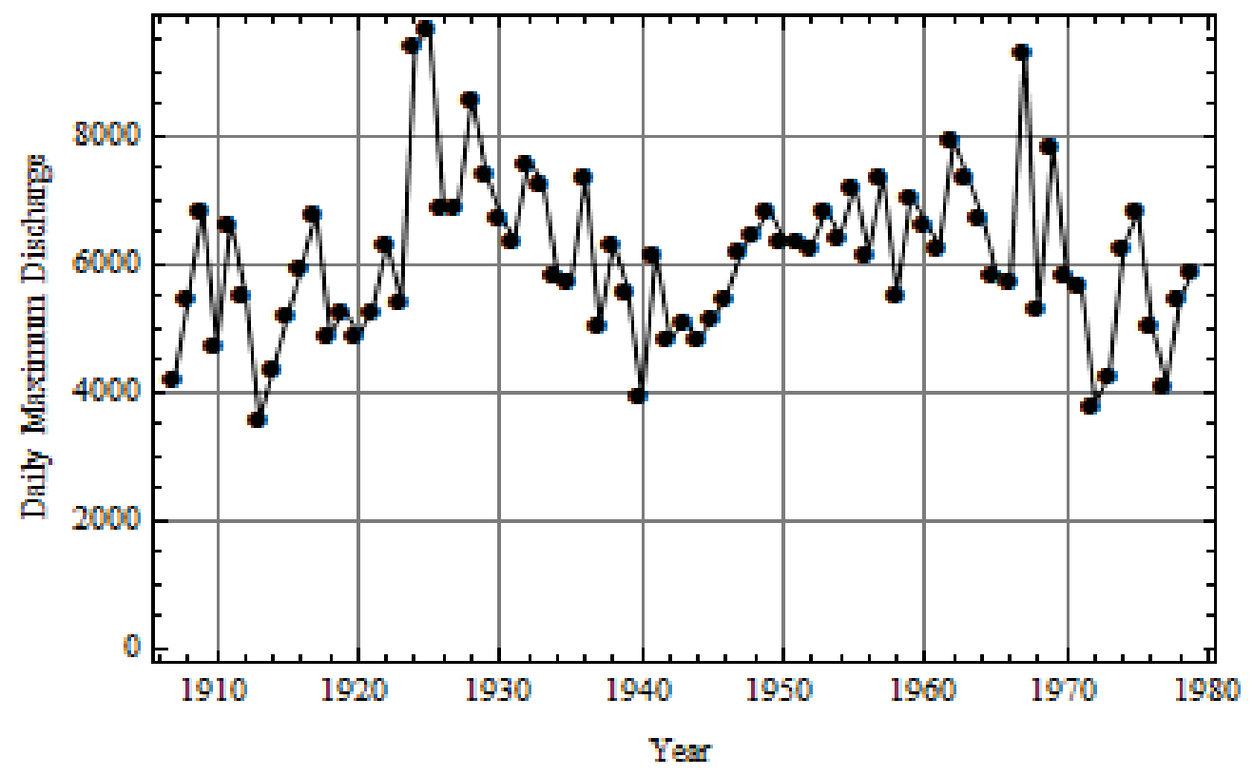
$s = 0.2890$

The figure depicts the station locations and the corresponding mean value differences. The vast majority of the stations do not indicate an increasing trend. Those with increasing values are fewer than 1/3 of those with decreasing trends.

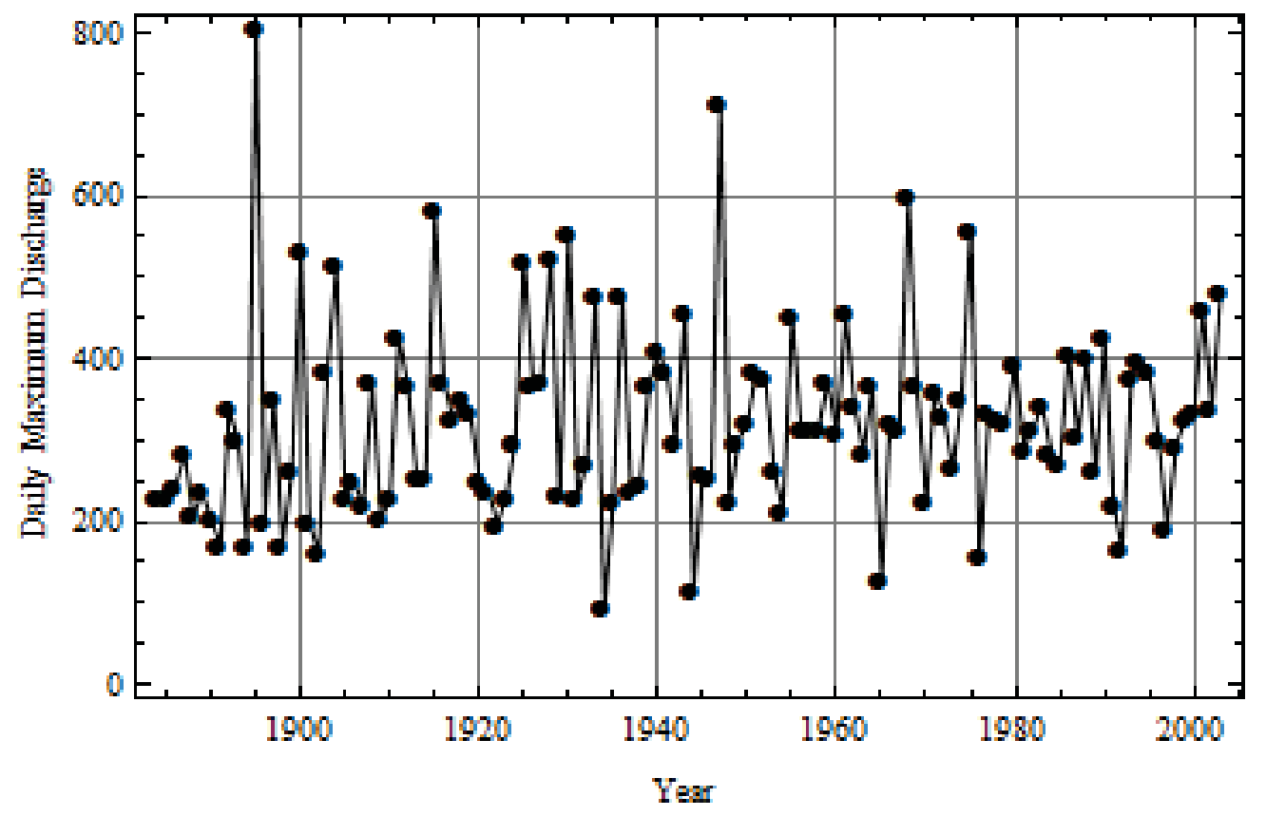
11. Hurst – Kolmogorov dynamics

A sample analysis showed that in the majority of time series the Hurst coefficient, H, is around 0.5, which does not indicate a Hurst-Kolmogorov behaviour.

There are a few stations with $H > 0.5$, which indicate long term persistence, as well as a few with $H < 0.5$, which indicate antipersistence. Examples are plotted.



$H = 0.76$
River Niger at Koulikoro (Mali)



$H = 0.42$
River Thames at United Kingdom

12. Conclusions

- The World Catalogue of Maximum Observed Floods (Herschy, 2003) and its supplementary documentation, provide a good basis for assessing flood trends worldwide.
- Analysis of trends and of aggregated time series on climatic (30-year) scale does not indicate consistent trends worldwide. Despite common perception, in general, the detected trends are more negative (less intense floods in most recent years) than positive. Similarly, Svensson et al. (2005) and Di Baldassarre et al. (2010) did not find systematical change neither in flood increasing or decreasing numbers nor change in flood magnitudes in their analysis.
- Future work will try to investigate the reasons for the decreasing trends at each of the basins, with particular emphasis on whether the river basins upstream the gauging location are intact or perhaps affected by human activities.

References

- Centre for Research on the Epidemiology of Disasters (CRED) (2004), EM-DAT The International Disaster Database, http://www.emdat.be/database, Univ. Catholique de Louvain, Louvain, Brussels.
- Di Baldassarre, G., A. Montanari, H. F. Lins, D. Koutsoyiannis, L. Brandimarte, and G. Blöschl, Flood fatalities in Africa: from diagnosis to mitigation, *Geophysical Research Letters*, 37, L22402, doi:10.1029/2010GL045467, 2010
- Kundzewicz ZW, Robson AJ Change detection in river flow records—review of methodology. *Hydrological Science Journal 49(1):7–19*, 2004
- Milly P.C.D., R. T. Wetherald, K. A. Dunne & T. L. Delworth, Increasing risk of great floods in a changing climate, *Nature* 415, 514-517, 2002
- Papalexiou, S.M., and N. Zarkadoulas - The trendy trends: a fashion or a science story? , *European Geosciences Union General Assembly 2009, Geophysical Research Abstracts, Vol. 11*, Vienna, 8422-2, European Geosciences Union, 2009.
- Herschy R., *World Catalogue of Maximum Observed Floods*, IAHS Press, 2003
- Svensson, C., Kundzewicz, Z.W., Maurer, T., 2005. Trend detection in river flow series: 2 Flood and low – flow index series. Hydrological Sciences Journal 50 (5), 811–824.