European Geosciences Union
General Assembly 2011

Vienna, Austria, 03 - 08 April 2011

Session: HS7.4/AS4.9/CL3.4
Hydrological change versus climate change

Long-term properties of annual maximum daily rainfall worldwide

Available online:
http://itia.ntua.gr/en/docinfo/1124/
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1. Abstract

From a large data base of daily rainfall, several thousands of time series of annual maxima are extracted, each one having at least 100 years of data values. These time series are analyzed focusing on their long-term properties including persistence and trends. The results are grouped by continent and time period. They allow drawing conclusions, which have some importance, given the ongoing and intensifying discussions about worsening of climate and amplification of extreme phenomena.

Acknowledgment: This research is conducted within the frame of the undergraduate course "Stochastic Methods in Water Resources" of the National Technical University of Athens (NTUA). The School of Civil Engineering of NTUA provided financial support for the participation of the students in the Assembly.

2. The data set

Changes in extreme phenomena such as precipitation and temperature during the last decades of the 20th century are under intense discussion in the scientific community.

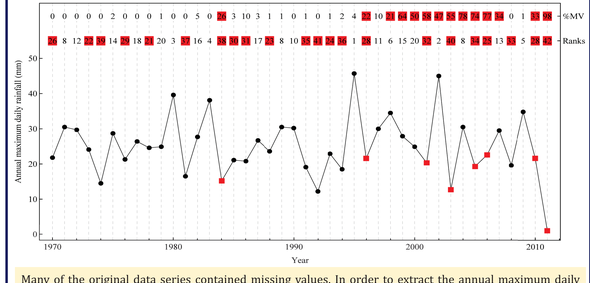
In this study we are trying to contribute to further discussion on this subject, focusing on extreme precipitation events. In order to do this we examine data from the GHCN-Daily database.

GHCN (Global Historical Climatology Network)-Daily is a database that contains daily temperature, precipitation, and snow records from more than 40000 stations distributed across all continents. [Available online: http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/index.php]

In this study we examined annual maximum daily precipitation records. From the total number of stations we selected 3070 fulfilling the following criteria:

1. Each time series contains not less than 100 years of data.
2. Each time series contains not less than 80 non-missing years of data.
3. In each time series the percentage of non-missing values does not exceed 20%.
4. As we are particularly interested in the period after 1970, we demand this period to contain at least 30 non-missing values.

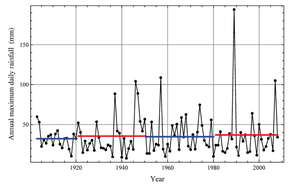
3. Extraction of time series of maxima

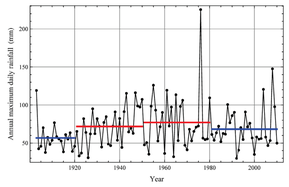


Many of the original data series contained missing values. In order to extract the annual maximum daily time series, we proceed as follows: (a) We extract the annual daily maximum values, (b) we estimate the rank of each value within the time series (the largest value has rank 1), (c) we estimate from the daily time series the percentage of missing values in each year, and (d) we form the final annual daily maximum time series by removing the values with percentage of yearly missing values larger than 2/12 (approximately two months of missing values) if the rank is larger than that of the sample's half length. The method is graphically explained in the figure above. Values with rank and missing-value percentage both coloured red are removed.

4. Long-term persistence

The analysis of data showed that in the majority of time series the Hurst coefficient is around 0.5, which does not indicate a Hurst-Kolmogorov behaviour. The Hurst coefficient of the time series plotted on the right is approximately 0.5. The station is located in south Australia in Woomera (Purple Downs).

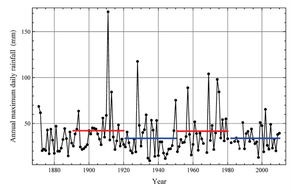


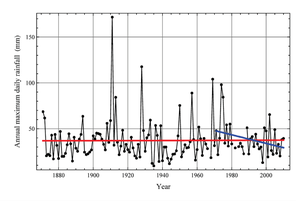


However, there are a few stations with H > 0.5, which indicate long term persistence.
The Hurst-coefficient of the time series plotted on the left is approximately 0.79. The station is located in east Australia in Legume (New Koreelah).

5. Statistical indices

The time series of the annual maximum daily rainfall are split into four periods of 30 years (1890-1920, 1920-1950, 1950-1980, 1980-2010). For each station the climatic (30-year) mean for each of the four periods is calculated, given that the period contains not less than 15 non-missing values.
In the example plot on the right blue and red lines indicate climatic means lower and higher than the overall mean, respectively.

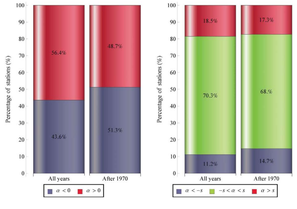


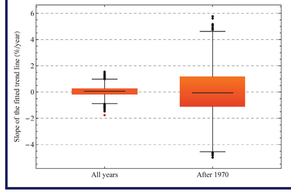


We also fit trend lines to the annual maximum daily rainfall time series and calculate their slopes. Trend lines are fitted for the entire period (red line) and the most recent 40-year period 1970-2010 (blue line). This particular example is from the Wentworth Post Office station located in south-eastern Australia.

6. Trend analysis

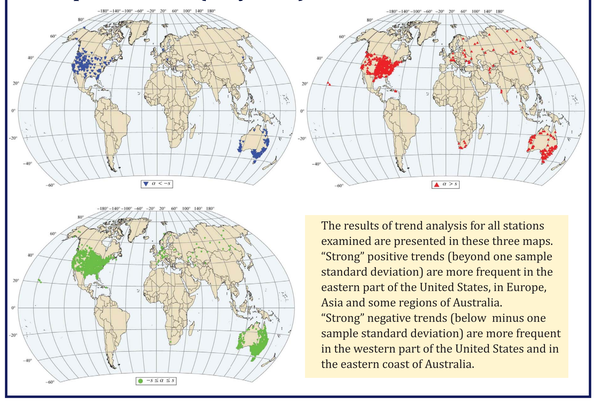
All 3070 stations fulfilling the criteria set are examined for trends.
For the entire period, 1731 stations show positive slope and 1339 negative slope.
For the most recent 40 years, 1494 exhibit positive slope and 1576 negative slope.
"Strong" negative trends beyond one sample standard deviation have become more frequent compared to those the entire period, while "strong" positive trends have become slightly less frequent.





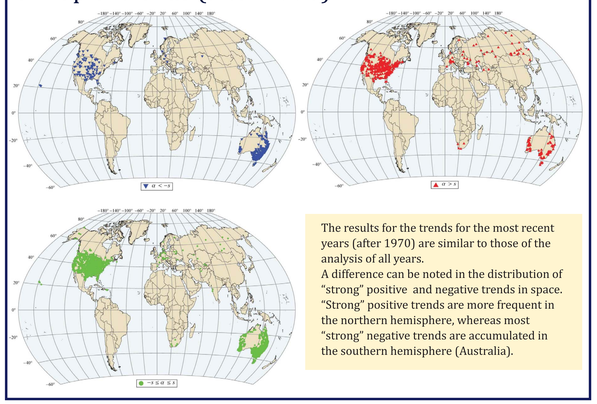
We can observe from the box plot for all years that 50% of the trends vary from -0.2%/year to 0.3%/year and 90% of the trends vary from -0.5%/year to 0.7%/year.
For the 40-year period after 1970, 50% of the trends vary from -1.1%/year to 1.2%/year.
The median and mean values are 0.06%/year for all years and 0% for the most recent 40 years (after 1970).

7. Map of trends (all years)



The results of trend analysis for all stations examined are presented in these three maps.
"Strong" positive trends (beyond one sample standard deviation) are more frequent in the eastern part of the United States, in Europe, Asia and some regions of Australia.
"Strong" negative trends (below minus one sample standard deviation) are more frequent in the western part of the United States and in the eastern coast of Australia.

8. Map of trends (after 1970)

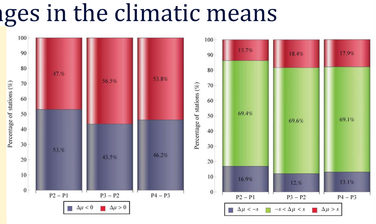


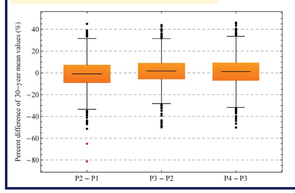
The results for the trends for the most recent years (after 1970) are similar to those of the analysis of all years.
A difference can be noted in the distribution of "strong" positive and negative trends in space. "Strong" positive trends are more frequent in the northern hemisphere, whereas most "strong" negative trends are accumulated in the southern hemisphere (Australia).

9. Analysis of changes in the climatic means

To extract these results we examine the difference of means between consecutive 30-years periods
- 2nd - 1st period: 2169 stations fulfil the criteria
- 3rd - 2nd period: 3046 stations fulfil the criteria
- 4th - 3rd period: 3067 stations fulfil the criteria

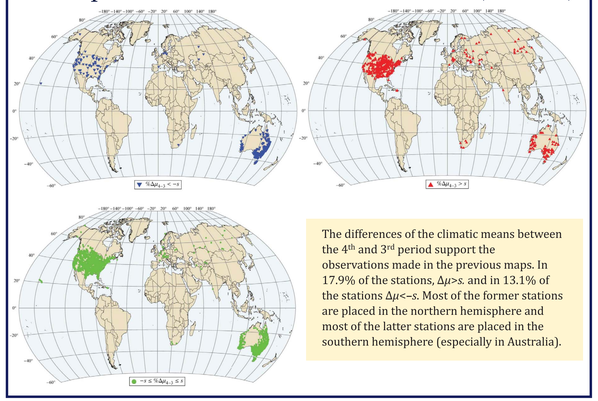
The standard deviations of the differences between two consecutive periods are 12.9%, 11.5% and 12.5% respectively.





We can note that 50% of the differences of the climatic means vary from -9% to 9% and 90% of the differences vary from -20% to 21%.
For the two most recent periods (P4 – P3, P3 – P2) the median and mean values are about 1% whereas for the first period (P2 – P1) about -1%.

10. Map of differences of climatic means (P4 – P3)

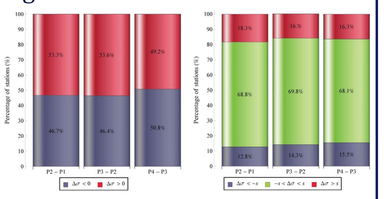


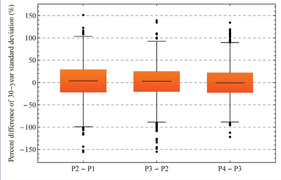
The differences of the climatic means between the 4th and 3rd period support the observations made in the previous maps. In 17.9% of the stations, $\Delta\mu > s$. and in 13.1% of the stations $\Delta\mu < -s$. Most of the former stations are placed in the northern hemisphere and most of the latter stations are placed in the southern hemisphere (especially in Australia).

11. Analyses of changes in the standard deviations

To extract these results we examine the difference of the 30-year standard deviations between consecutive periods
- 2nd - 1st period: 2169 stations examined
- 3rd - 2nd period: 3046 stations examined
- 4th - 3rd period: 3067 stations examined

The standard deviations of the differences are 37.8%, 34.8% and 34.3% respectively





We can note that 50% of the differences of the standard deviations vary from -22% to 29% and 90% of the differences vary from -57% to 64%.
Median and mean values for each period:
- P2 – P1: 3.6%
- P3 – P2: 2.2%
- P4 – P3: about 0.0%

We can notice a decreasing trend especially in the last period.

12. Conclusions

- We analyze all 3070 GHCN stations of annual maximum daily rainfall that have at least 100 years of data values (and fulfil specific criteria about missing values), in order to identify possible changes in statistical properties of rainfall over time.
- Statistical indices estimated include: (a) trends for all years, (b) trends after 1970, (c) percent differences of climatic means, and (d) percent differences of climatic standard deviations.
- For the entire period (more than 100 years) positive trends are more common than negative trends (56% *vs.* 44%, respectively). However, for the most recent 40-year period (after 1970) the positive trends become slightly less common than negative ones (49% *vs.* 51%, respectively).
- By partitioning the study period into consecutive 30-year periods, we observe that for the older periods (P2 – P1) negative differences in the climatic means are more frequent (53% of the stations), while in the most recent periods positive differences become more frequent (57% for P3 –P2 and 54% for P4 – P3).
- "Strong" positive trends and positive differences in the means are more frequent in the northern hemisphere (eastern part of the United States, Europe, Asia) while "strong" negative trends and negative differences in the means are more frequent in the southern hemisphere (eastern coast of Australia).
- Overall, changes, in the climatic regime of rainfall occur all the time. They are both negative and positive and in many cases indicate clustering in space and time rather than a general and uniform worsening of the climate.