Trends in temperature extremes in Morocco

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Abstract

The heat wave in Maghreb during the summer of 2012 had very bad consequences in Algeria, causing several casualties and emergency hospitalizations, and in Morocco where the agricultural sector was hit by losses of 12 million Euros for poultry farmers. This work aims to analyze the frequency of warm and cold extreme events in two Moroccan regions (the Bouregreg and the Tensift). This study considers long-term daily data of maximum and minimum temperatures, recorded in the stations of Marrakech, Safi, Kasba-Tadla and Rabat-Sale. The temperature extremes are defined as the daily data above (below) the 95th or 99th (5th or 1th) percentiles. Results show upward trends in maximum and minimum temperatures of both regions. Trends are larger for minimum temperature, during the warm season, and are mostly significant in coastal stations. Changes in cold events are larger than those for warm events and very cold events decrease significantly in the whole studied area. The southern region (Tensift) is the most affected with the changes of the temperature regime. A statistical link is observed between the extreme temperature events during the summer and the Mediterranean Oscillation index while the circulation related to the North Atlantic Oscillation doesn't affect recorded extreme events.

Introduction

Because of the IPCC statements' about extreme events (IPCC 1990; 1995; 2001; 2007), the understanding of their changes becomes a critical factor to the knowledge of recent and future global climate change and yet an important focus of the current scientific research. Furthermore, the comprehension of the atmospheric mechanisms that control extreme weather leads the way in risk assessment and development of mitigation strategies for socio-economic fields. According to the IPCC, an extreme weather event is a rare event within its statistical reference distribution at a particular place (IPCC 2001). Definitions of "*rare*" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. An extreme weather event may not cause damages because the impact of extremes on natural and human systems is highly location-dependent and it is linked to the vulnerability of the places affected by the extremes.

Aim

To study the evolution of warm and cold extreme events in two Moroccan regions (the Bouregreg and the Tensift basins) and to determine their relationship with the atmospheric circulation.

Materials and methods

The study covers the regions of Bouregreg and Tensift watersheds (Fig1).
Quality controled maximum and minimum temperatures data of the stations of Rabat-Salé, Kasba Tadla, Safi and Marrakech were used (Table 1).

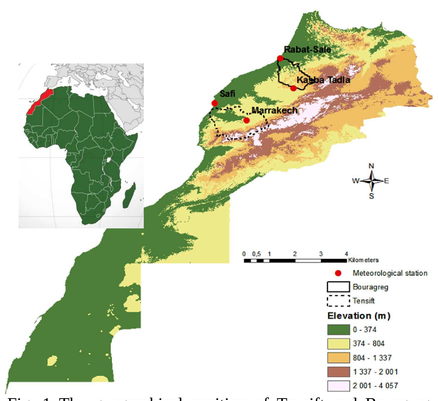

Fig. 1 The geographical position of Tensift and Bourgerg watersheds on the map of Morocco

Weather Station	Region	Cold Season				Warm Season			
		Maximum Temperatures		Minimum Temperatures		Maximum Temperatures		Minimum Temperatures	
		Lengths of time series	Missing data	Lengths of time series	Missing data	Lengths of time series	Missing data	Lengths of time series	Missing data
Rabat-Salé	Bouregreg	1950-2009	0%	1950-2009	0%	1950-2009	0%	1950-2009	0%
Kasba Tadla	Bouregreg	1983-2010	0%	1983-2010	0%	1983-2010	0%	1983-2010	0%
Safi	Tensift	1955-2010	2%	1955-2010	2%	1973-2010	0%	1955-2010	2%
Marrakech	Tensift	1941-2010	0%	1941-2010	0%	1941-2010	0%	1941-2010	0%

Table. 1 Lengths of daily maximum and minimum temperatures time series

The yearly data of the North Atmospheric Oscillation (NAO) and the Mediterranean Oscillation (MO) from the Climatic Research Unit (CRU) website (www.cru.uea.ac.uk/cru/data) were used in order to study the correlation between these two atmospheric modes and the evolution of hot and cold events between 1983 and 2009 during the warm and the cold seasons respectively.

Seasons identification: A dry month has an average rainfall equal or less than twice its average temperature (P ≤ 2T °) (Bagnouls and Gaussen 1953; 1957). The cold and the warm seasons were identified according to the stations' climatograms.

Estimating trends: The method of Sen estimates the slope assuming that the trend is linear, it involves computing slopes for all the pairs of ordinal time points and then using the median of these slopes as an estimate of the overall slope (Theil 1950 ; Sen 1968). The statistical significance of trends was investigated using the Mann-Kendall non parametric test, applied with a confidence level of 95%.

Estimating correlations : The Kendall's tau coefficient of correlation was used in order to study the strength of the monotonic relationship between time series.

Identification of extreme events of maximum and minimum temperature

The following concepts were formalized:

- **A one day hot (cold) event is a day that recorded a maximum (minimum) temperature greater (lower) than or equal to the 95th (5th) percentile;**
- **A one day very hot (cold) event is a day that recorded a maximum (minimum) temperature greater (lower) or equal to 99th (1th) percentile;**
- **A hot (cold) event of more than 3 days is a succession of 3 or more days of hot (cold) events;**
- **A very hot (cold) event of more than 3 days is a succession of 3 or more days of very hot (cold) events.**

Macro-scale atmospheric patterns and very rare extreme events

Correlations between very cold and very hot temperature events and NAO and MO are investigated on a seasonal timescale between 1983 and 2009, using the Kendall's tau coefficient of correlation.

Uncertainties

In data

- Only a few number of stations is available for each region: more stations from outside the basins are to be recovered or regional climate models driven by reanalysis and available at a fine spatial resolution could be analyzed, since they usually reproduce temperature with a good adequacy;

- The common period of data is small: the main conclusions focus on the results obtained over the full period available in each station;

- Missing data are observed: application of the Kuglitsch (2010) criteria for the elimination of datasets with several missing data. These criteria are:

*** A month is considered complete when it contains no more than three missing days;**

*** A season is considered as available when all months are complete in respect to criterion 1;**

*** A station dataset is considered as complete when no more than three consecutive seasons are missing.**

In Results and interpretations

- Significance of statistical results : Application of the Mann Kendall test;

- The response of small scale regions to the recent global warming depend on the region characteristics: more regional studies are needed.

Results

The cold season : November, December, January and February.
The warm season : June, July, August and September (Fig2).

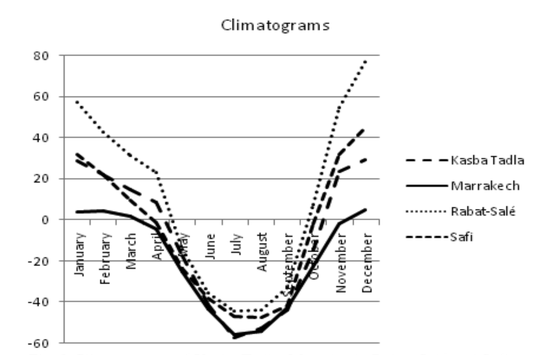

Fig. 2 Climatograms of Kasba Tadla, Marrakech, Rabat-Salé and Safi

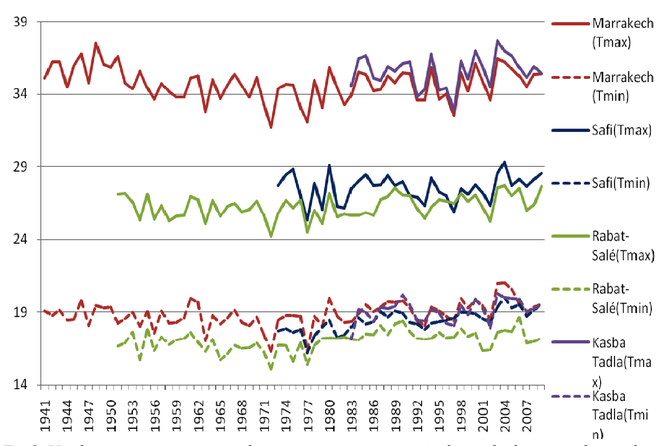

Fig.3: Yearly average minimum and maximum temperatures in the studied stations during the warm season

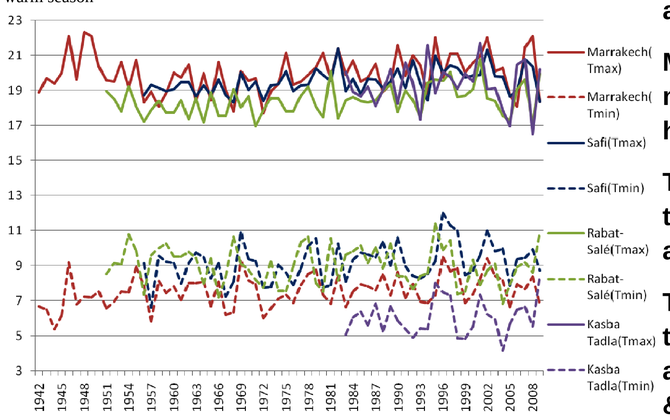

Fig.4: Yearly average minimum and maximum temperatures in the studied stations during the Cold season

Most of the observed trends during the common period of data (1983-2009) are not statistically significant. Main conclusions focus on the results obtained over the full period available in each station.

Most of the estimated trends in seasonal mean maximum and minimum temperatures have large and positive magnitudes.

The trend magnitudes in both basins are of the same order, no discernible spatial trend appears in the datasets.

The trends are larger for minimum temperature mainly during the warm season and they are mostly significant in coastal stations (fig3 & 4).

At the seasonal scale, the rate of change in percentile-based maximum temperature events is different between the cold and warm seasons. No pronounced trends were found in hot and very hot events lasting for 3 days or more. Changes in cold temperature extremes are larger than those for warm temperature extremes and very cold events decreased significantly during both seasons in the studied area (fig5 & 6).

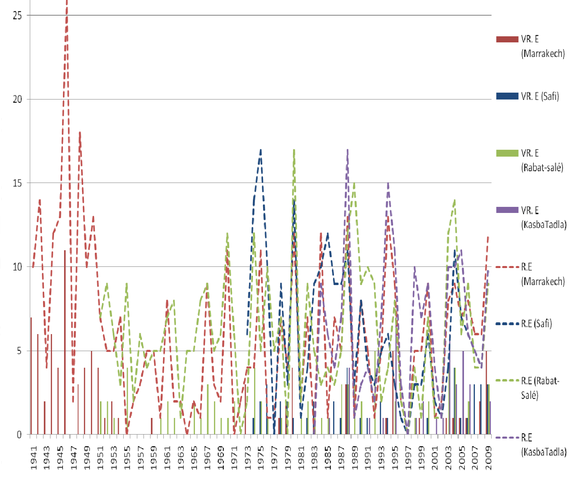

Fig. 5 Evolution of hot and very hot events in the studied stations during the warm season; R.E: Rare Events; V.RE: Very Rare Events

Extreme temperature events recorded in the four stations during the warm season are influenced by the MO. This influence is higher in the southern region (The Tensift area) indicated with stronger correlation coefficients. The circulation related to the NAO affects the events recorded in Rabat-Sale only (Table 2).

Site	Kendall's Tau coefficient		Kendall's Tau coefficient	
	NAO and extreme maximum temperature events (Warm Season)	NAO and extreme minimum temperature events (Cold Season)	MO and extreme maximum temperature events (Warm Season)	MO and extreme minimum temperature events (Cold Season)
Rabat-Sale	**0,301**	-0,076	**0,283**	-0,012
Kasba-Tadla	-0,101	-0,074	**0,292**	0,050
Safi	0,148	-0,054	**0,355**	0,101
Marrakech	-0,099	-0,086	**0,320**	0,055

Table. 2 Seasonal correlations between NAO and MO and extreme temperature events, Bold Character: trend is statistically significant, Significance level=0.05

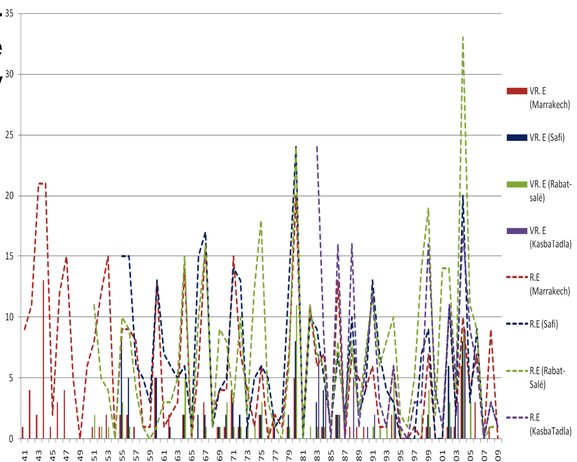

Fig. 6 Evolution of cold and very cold events in the studied stations during the cold season ; R.E: Rare Events; V.RE: Very Rare Events

Conclusion

The results of this study highlight the fact that, the response to the recent global warming depends on the considered region characteristics and emphasize the need for regional studies. It would be worth while making such a study on other areas from Morocco, if more long daily data records were to be recovered. Obtained results could then be compared with those of the present study. As a surrogate for station data, regional climate models driven by reanalysis now available at a fine spatial resolution could be also analyzed, since they usually reproduce temperature with a good adequacy. However as a note of caution, the findings of this study refer to the recent past and do not allow speculation about future evolution and trends, yet they might be of major importance for policymakers designing risk-prevention procedures as well as socio-economic strategies.

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