تقييم الاتجاه العام لتغير الهطولات المطرية في سورية خلال الفترة (1955-2006)

Assessment of Precipitation in Syria, Trend Analysis, During the Period of (1955-2006)

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الملخّص

بالنظر إلى الاتجاه العام للانحدار في كميات الهطول خلال فترة زمنية طويلة يلاحظ أن أي تغير مطرد في معدلات وخصائص الهطول (الشدة والتكرار والاستمرارية) ينتج عنه آثار بيئية كبيرة، لذلك فإن دراسات الاحتباس الحراري تهتم بالتبدلية المناخية. هناك صعوبة في تقدير مؤشرات التغيرات المناخية لقيم الهطولات والتي تنجم أحيانا عن نوعية البيانات وأخطاء في قياس كميات الهطول وأحيانا أخرى عن عدم توفر بيانات لفترات زمنية طويلة، وبما أن الهطولات متغيرة زمنيا ومكانيا فإنه يمكن أحيانا رصد تغير في انحدار الهطول خلال سلسلة زمنية قصيرة نسبيا، يكون هذا التغير يكون جزءً من تبدلية مناخية حقيقة في قيم الهطول، لذلك يجب توخي الحذر عند تحليل انحدار قيم الهطولات.

حُللت بيانات الهطولات المطرية في اثني عشر محطة مناخية موزعة في سورية للفترة الزمنية 1955 إلى 2006، لتحديد مدى تأثر انحدار هذه القيم بظاهرة الاحتباس الحراري. كما أختبر تطبيق اختبار Mann-Kendall لدراسة انحدار قيم الهطولات الفصلية والسنوية، فلوحظ أن هناك زيادة أحيانا في قيم الانحدار ونقصاً في أحيان أخرى عند مستوى ثقة 90 و 95 %.تتوافق هذه النتائج مع دراسات مشابهة في الدول المجاورة والتي تؤكد زيادة قيم الانحدار (زيادة في المعدل الفصلي لمجموع كمية الهطول) في فصل الخريف لمعظم المحطات المدروسة وذلك بمعدل 2 إلى 15 % لكل عشر سنوات (عَقد) مقابل 4 % لكل عقد على قيمة الهطولات السنوية. من ناحية أخرى كان هناك نقص في قيم الانحدار (تناقص في المعدل الفصلي لمجموع كمية الهطول) في فصلي الشتاء (بمعدل 5 إلى 7 % لكل عقد) و الربيع (9 إلى 12 % لكل عقد).

الكلمات المفتاحية : التغيرات المناخية، الهطولات المطرية، انحدار، اختبار Mann-Kendall، سورية.

Abstract

With respect to precipitation trends, there is no doubt that any persistent change in precipitation pattern or in the characteristics of the precipitation (intensity, frequency and duration), would have significant consequences for the environment. Thus global warming studies pay special attention to the crucial climate variable. There are, however, difficulties in identifying climate change signals in precipitation. Some of these difficulties are related to the quality of the data, errors in measuring precipitation, the length of the precipitation data highlights another difficulty in tracking the climate change signals, since precipitation is temporally, as well as spatially distributed, a highly variable parameter. Sometime it is possible to detect a trend in a short time series of precipitation, which, in reality, could be a part of long-

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term variability. Therefore, care has to be taken when interpreting the trend analysis of precipitation data.

To estimate the climate change and to observe trends in precipitation, precipitation records for the period of 1955-2006 were used to identify climatic trends and to determine to what extent these trends are potentially attributable to global warming. Although recent changes in atmospheric variability are associated with broad precipitation climate change, the Mann-Kendall trend test was applied to examine seasonal and annual precipitation data. Significant positive and negative trends at the 90 and 95% significance levels were detected. Furthermore, like most of the Regional researches, significant trends in precipitation occur most commonly during autumn, where seven of the twelve stations exhibit significant increases of 2 - 15 %/decade and Annual of 4 % /decade. The significant decreases in winter precipitation were 5-7 %/decade and in spring of 9-12 % /decade.

Key Words: Climate change, Precipitation, Trend, Mann-Kendall test, Syria.

Introduction

The Mediterranean area is a climate-sensitive region, which is climatically stressed by limited water resources and extremes of heat, which help to create or exacerbate existing socio-political tensions (Mann, 2001). Especially a high frequency (monthly, seasonal, annual and interannual) as well as low-frequency (interdecadal) variations of precipitation plays a crucial role in the management of regional agriculture, ecosystems, environment and socio-economic and water resources (Xoplaki et *al.,* 2000). Figure 1 presents the linear trends of wet season station precipitation (50mm/y) for the period of 1950-1999. Stations with a significant trend (90% confidence level, based on the Mann-Kendall test) are encircled (Xoplaki, 2002).

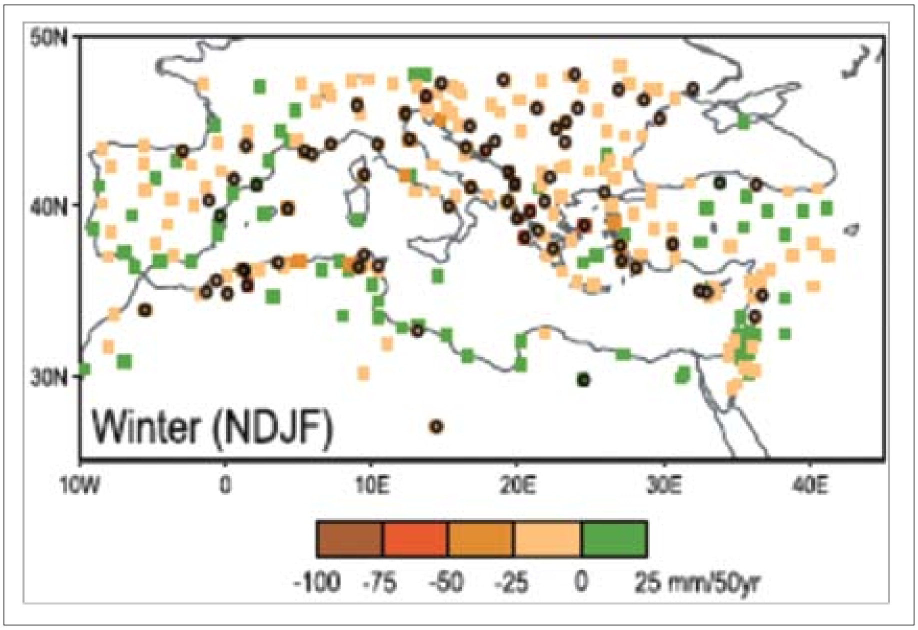

Figure 1. Linear trends of wet season station precipitation (50mm/ y) for the 1950-1999 periods. Stations with a significant trend (90% confidence level, based on the Mann-Kendall test) are encircled (from Xoplaki, 2002)

Recent studies revealed that the twentieth century was characterized by significant precipitation trends at different time and space scales (New et *al.,* 2001; Giorgi, 2001) found negative winter precipitation trends over the larger Mediterranean land-area for the twentieth century. Using the same data, (Jacobeit, 2000) showed for the last three decades some rainfall increases in autumn (western Iberia and southern Turkey), but at the same time a dominating decreases in winter and spring was observed. A glance at the Mediterranean regional precipitation trends for the period of 1950-1999 reveals a more detailed picture of the general results. Sub regional variability is high, particularly in areas with contrasted topography near coastland significant trends in the variability and monthly totals have been observed (Turkes¸ 1996; 1998). The data of Xoplaki (2002), shown in Figure 1, suggested a significant trend of precipitation in Syria, a region of Mediterranean that is significant with respect to perspiration decreases. Here, we present meteorological data for the period of 1955 -2006 from twelve stations distributed throughout Syria. The stations represent all geographical locations. Seasonal and annual time series of precipitation are investigated with the Mann-Kendall test to determine the presence of long-term trends.

Materials and Methods

Meteorological data

Meteorological data for the period of 1955–2006 from twelve Syrian stations (Sweida, Damascus Int. AirPort, Homs, Al Rastan, Jaraplus, Aleppo, Idleb, Tartous, Meslmieh, DeirEzzor, Bou Kamal and Hassakha(are presented in figure 2.

Data for the period of 1955-2006 were obtained from the Monthly and Daily precipitation and from 120 Syrian stations dataset (Syria Meteorological Department, 2008), available from the National Climatic Data Center (NOAA). Average monthly precipitation time series were summed in table 1 into winter (December–February, DJF), spring (March–May, MAM), autumn (September–November, SON) and annual (December–November) time series for the period of (1955–2006).

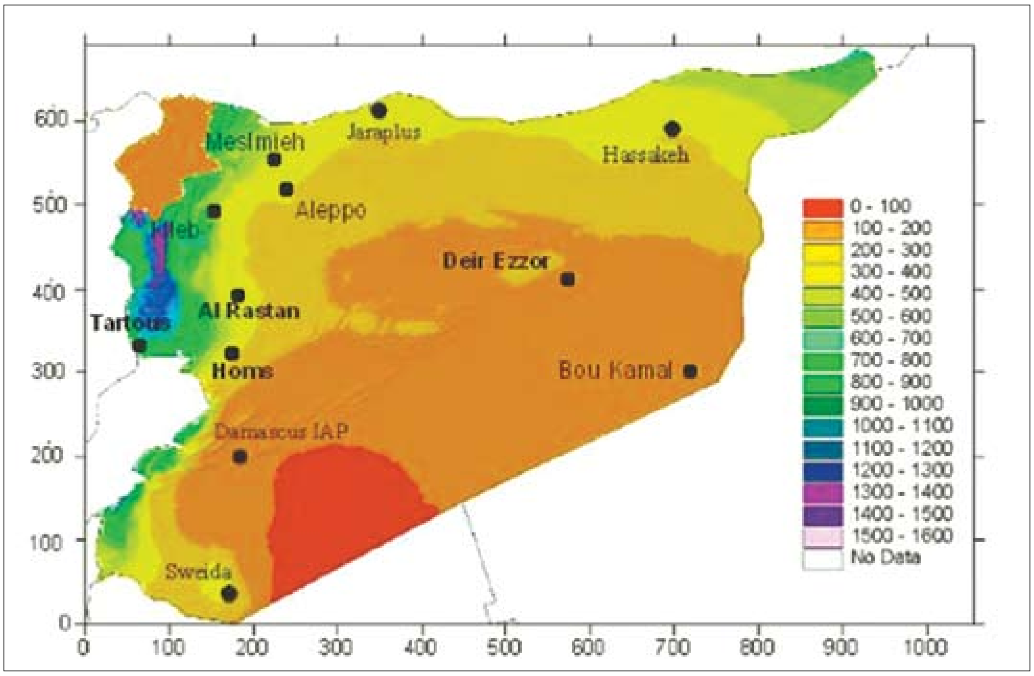

Figure 2. Locations of the twelve meteorological stations used in Syria.

The data set was analyzed for outliers, thus, detection and adjustment of such in homogeneities in the time series are made for those identified as outliers to a present threshold value according to (Barnett and Lewis, 1994). The adjustment was done following the procedure developed by (Hanssenand Forland, 1994). The twelve stations chosen for this study are located in relatively small cities, all with less than 300 000 inhabitants and most with significantly less than 50 000 inhabitants. Precipitation collection methods are inherently more problematic. In 1965, precipitation measurements within the Syrian Meteorological Department increased from two to four times daily, although this probably did not significantly alter the total amount of precipitation measured.

Table 1. Meteorological station records used in this study. Average Precipitation over the record period is given for December–February (DJF), March–May (MAM), September–November (SON) and December–November (annual). Met. Station Location Elev. (m) Record No. years

Met. Station	Latitude (N°)	Longitude (E°)	Elev. (meter)	Record	No. Years	Precipitation (mm)			
						DJF	MAM	SON	Annual
Sweida	32.55	36.61	1015	1955-2006	52	201.6	88.7	45.1	335.4
Damascus Int..	33.50	36.70	610	1955-2006	52	75.2	27.9	26.9	130.0
Homs	34.73	36.73	483	1955-2006	52	242.8	97.7	70.6	412.8
Al Rastan	34.94	36.74	390	1959-2001	42	205.3	92.0	65.7	362.3
Jaraplus	36.82	38.01	351	1955-2006	52	158.6	95.6	58.6	317.5
Aleppo	36.17	37.24	385	1955-2006	52	162.6	95.4	58.5	319.1
Idleb	35.93	36.61	451	1955-2006	52	280.4	131.2	84.3	499.8
Tartous	34.87	35.88	5	1957-2006	50	484.4	164.9	182.7	803.6
Meslmieh	36.32	37.22	415	1955-2006	52	161.4	93.4	62.6	320.0
DeirEzzor	35.34	40.14	215	1955-2006	52	76.6	52.4	23.0	152.3
Buo Kamal	34.57	40.68	175	1955-2006	52	62.4	45.2	18.3	125.8
Hassakha	36.61	40.68	307	1955-2006	52	128.6	96.9	41.3	267.7

Trend analysis and linear congruence with the North Atlantic Oscillation (NAO).

Seasonal and annual time series of precipitation was analyzed using the nonparametric Mann-Kendall test for monotonic trend (Mann 1945; Kendall 1975; Maidment 1993), which makes no hypothesis about the value of a parameter in a statistical density function. The Mann-Kendall statistic S is given by:

$$S = \sum_{t'}^{n-1} \sum_{t=t'-1}^{n} Z_k \qquad (1)$$

Where the ranked series Z_k is generated by first considering the annual time series

$$y_t, t = 1, n$$

Where: y_t : a variable

t : time step

n : number of time steps

And comparing each value

$$y_t, t = 1, n - 1$$

With all subsequent values

$$y_{t'}, = t' + 1, t' + 2, n$$

And applying the following conditions:

$$
\begin{aligned}
Z_k &= 1 \text{ if } y_t > y_t \\
Z_k &= 0 \text{ if } y_t = y_{t'} \qquad (2) \\
Z_k &= -1 \text{ if } y_t < y_{t'}
\end{aligned}
$$

The S statistic therefore represents the number of positive differences minus the number of negative differences found in $y_{t'}$. For n > 40, the standardized test statistic Z is obtained using a normal approximation:

Quelled

$$Z = \frac{s + m}{\sqrt{var(s)}} \qquad (3)$$

Where

$m = 1$ if $S < 0$, $m = 0$ if $S = 0$, and $m = -1$ if $S > 0$.

Because the Mann-Kendall test is based on ranks of the data only, a correction is needed for the effect of data ties on the variance of S. Data ties occur when adjacent entries have the same value or when two or more years of data are absent (missing values are replaced with the series mean). The correction is as follows:

$$Var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{i=1}^{n} t_i (t_i - 1)(2t_i + 5) \right] \qquad (4)$$

where n is the number of tied groups and t_i is the number of data in the i^{th} (tied) group . The null hypothesis (no trend) is rejected the $\propto$ significance level if $| z | > z(1 - \propto/2)$, where $z(1 - \propto/2)$ is the $1 - \propto/2$ quintile of the standard normal distribution. This study uses an exceedance probability of $p = 0.9$ ($\propto = 0.2$) to establish trend. A slope estimator is not used (Sen, 1968), asthe aim of this study is simply to establish the presence or absence of trend.

To estimate the potential contribution of the NAO on observed precipitation trends, we apply trend analysis similar (Rigor et *al.,* 2002). The analysis is as follows:

1– All-time series are linearly trended.

2– For each resulting time series, values of precipitation are regressed into associated NAO indices (where NAO indices are normalized by the series standard deviation).

3– The resulting regression coefficient is then multiplied by the linear trend in the associated NAO index time series (in units of standard deviations per decade).

4– This product is the component of the decadal temperature or precipitation trend that is “linearly congruent” with the NAO. Linear congruence does not necessarily imply that the NAO is driving the observed variance in precipitation, but it does identify likely connections between them.

Results and discussion

Departures of precipitation from their associated long-term record means (Table 1) are shown in Figure 3, positive values indicate above average anomalies and negative values indicate below average anomalies. This pattern is much less evident in records of precipitation departures, where little correlation in precipitation over relative board geographical area, between stations for a given year (Fig. 3, Table. 3). In contrast, inters annual variability in precipitation is the greatest during SON and the least during MAM. This largely exists owing to the significantly greater amount of precipitation falling in DJF as compared with SON (e.g. DJF precipitation averages more than twice that of MAM precipitation; Table 1). For this reason, DJF and MAM precipitation variability can drive shift back to SON in annual.

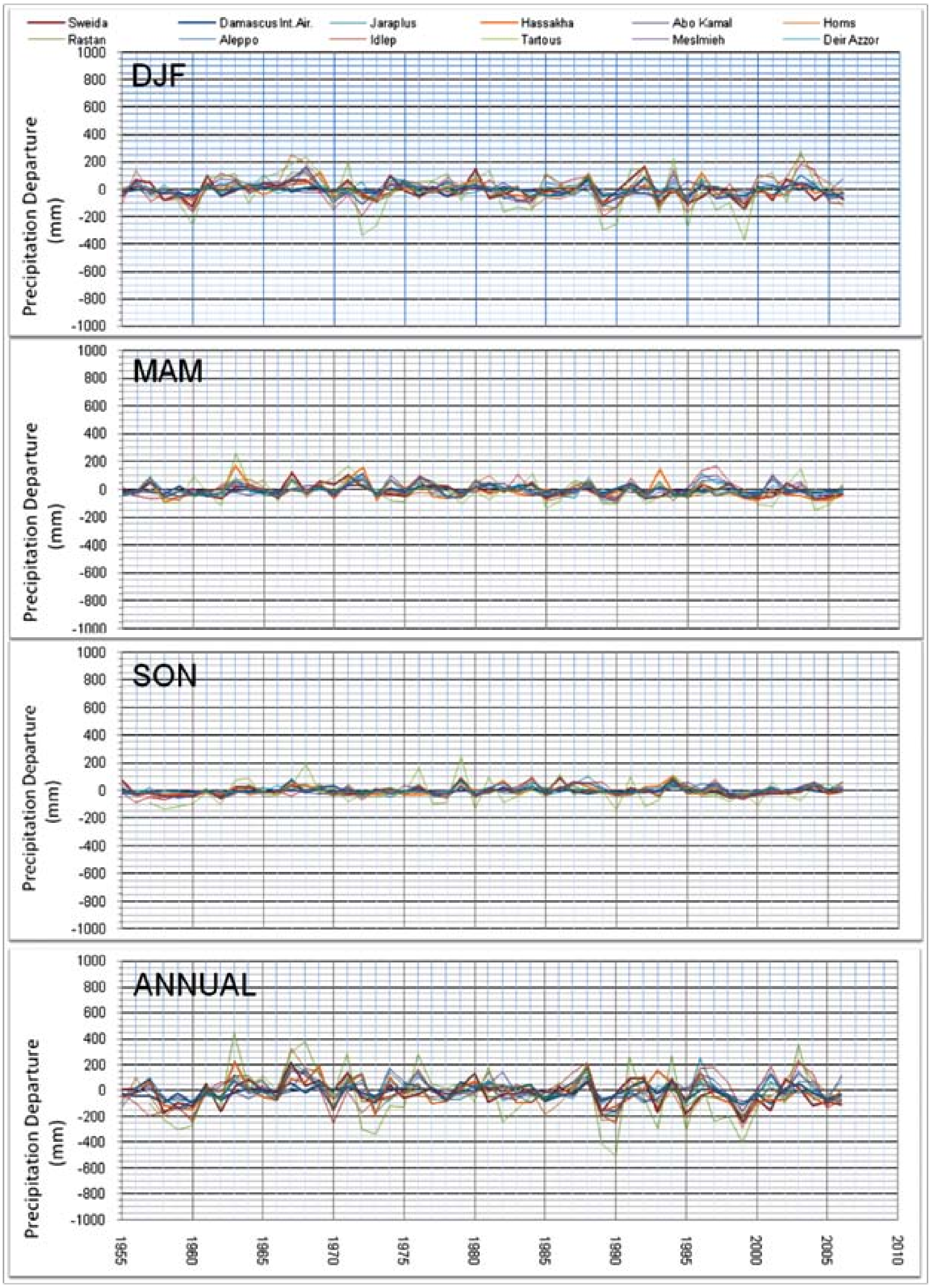

Figure 3. Departures of Precipitation for twelve Syrian stations. Plots are shown for December–February (DJF), March–May (MAM), September–November (SON) and December–November (annual). Departures are calculated from associated long-term record means.

Among the 48 seasonal and annual precipitation records analyzed, only 13 record (27 %) display trends at significance levels of p ≥ 0.90 (Table 2). From these 13 records, 8 records display trends at significance levels of p = 0.90, 3 records at p = 0.95, and 2 records at p = 0.99. Statistically significant trends are positive for seven station records in SON and annual (i.e. precipitation increase). But negative trends were found for DJF and MAM records (Table 3). Significant trends in precipitation are most commonly found during MAM (seven stations) and least commonly found during annual (one station). Seasonal trends range from –12 to +15 %/decade (–19.8 to +3.5 mm/decade). Annual trends equal 4 %/decade (+20 mm/decade) (Table 3). Statistically significant trends in precipitation are most commonly found at 36-37° N latitudes, with all but two of the significant trends occurred at stations north of 33°N.

Table 2. Mann-Kendall statistics for seasonal and annual time series (ca. 1955–2006) of Precipitation for twelve meteorological stations. Negative values indicate negative trends and positive values indicate positive trends. Significance levels: p = 0.90 (boldface), p = 0.95 (italicized boldface) and p = 0.99 (underlined, italicized boldface).

Met Station	precipitation (mm)			
	DJF	MAM	SON	ANNUAL
Sweida	-1.02	-1.61	-0.65	-1.59
Damascus Int.Air.	-0.43	0.11	0.80	0.23
Homs	-1.40	-1.59	0.64	-1.07
Al Rastan	-1.80	-1.05	-0.22	-1.32
Jaraplus	-1.65	-0.02	1.67	-0.36
Aleppo	-0.61	-0.31	2.91	0.18
Idleb	0.75	1.13	2.45	1.74
Tartous	-0.32	-1.66	0.90	-0.74
Meslmieh	-1.48	0.12	2.72	-0.16
DeirEzzor	-0.25	-0.48	1.93	0.40
Buo Kamal	-0.01	-0.68	1.68	0.15
Hassakha	-0.62	-0.88	2.20	0.56

Table 3. Estimated decadal trends in precipitation (ca. 1955–2006) for those records displaying statistically significant (p ≥ 0.90) Mann-Kendall statistics.

Met. Station	precipitation (% / decade)			
	DJF	MAM	SON	ANNUAL
Sweida		-9		
Damascus Int.Air.				
Homs		-9		
Al Rastan	-7			
Jaraplus	-5		10	
Aleppo			13	
Idleb			11	4
Tartous		-12		
Meslmieh			13	
DeirEzzor			15	
Buo Kamal			10	
Hassakha			2	
Trend Average	-6	-10	11	4

The most robust findings of this study are strong and prevalent increases in autumn precipitation since 1955. The results showed that the variability of around 30% of the total Syrian September to May precipitation (Table 3), can be accounted for a combination of four large-scale geopotential height fields and sea level pressure (Xoplaki et *al.,* 2005), specially when compared with the Mediterranean variability precipitation over the past 40 years. The most evident result from the precipitation records examined is a general increase in autumn precipitation throughout Syria. It is possible that since station gauges measure rain with more accuracy than snow, a portion of the precipitation increases found during SON could be due to a transition from snowfall events to more rain events. Thus leads to erroneous observations of decreasing winter precipitation. However, the fact that even for stations exhibiting the strongest increases in SON precipitation during these months are still well below freezing throughout the entire record, suggests that a significant increase in rain events is unlikely. Although the trends found in SON precipitation may be small in terms of magnitude, they are substantial in terms of percent increase. For instance, the observed ca. 14.4 mm/decade decrease in DJF precipitation at Al Rastan represents a 7 % decrease in DJF precipitation over the 52-year record. Similar findings of decrease winter precipitation have been found over the past 45 years in Italy. These results indicate that, in Italy, there has been a general tendency towards a decrease in winter precipitation over the 1951–1996 period (Michele et *al.,*1996). A decrease of winter precipitation over the whole Greek was found, in the case of winter precipitation, less than 7% of variance is explained (Xoplaki et *al.,* 2000). In this study, significant precipitation trends are found most commonly at higher latitudes, with 8 of the 13 significant trends occurring at stations north of 34° N. Significant precipitation trends are positive for all stations except Sweida, Homs, Al Rastan and Tartous, where all records display negative trends. Tartous also tends to be much drier than any other station (Table 1). This northward shift in cyclone activity is important as cyclones are one of the main factors setting the variance of temperature, pressure, and moisture in the troposphere on timescales of 2.5 - 10 days (Paciorek et *al.,* 2002). A recent increase in cyclone activity has been observed over high latitude Northern Hemisphere regions and Eurasia, coincident with the recent increase in the AO and northward shift in Northern Hemisphere storm tracks. Paciorek et *al.,* (2002) find an increase in winter cyclone intensity over Eurasia over the past ca. 50 years. The recent persistence of Arctic cyclone activity has been linked to relatively large reductions (particularly along the Syria sector) in Northern Hemisphere sea ice cover, which may in part occur because enhanced southerly winds advent the ice poleward away from the coasts (Serreze et *al.,* 1995; Maslanik et *al.,* 1996). Rigor et *al.,* (2002) suggest that these changes in sea ice may in turn be responsible for recent observed trends in surface air temperatures, by way of increased latent heat released during formation of new ice in diverging leads and increased heat flux through thinner ice. The strong inter annual and spatial variability in precipitation may in part be due to the contribution of convection. Convective weather patterns are much more spatially variable than synoptic-scale patterns and are much less likely to correlate well with the AO. Increased convection could also contribute to observe warming through enhanced downward long wave radiation (Stone, 1997). Although the cyclonic circulation show a significant decrease in the Western Mediterranean, mostly in winter and spring, and an increase in the Eastern, mainly due to the summer and autumn increase in the frequency of thermal lows (Guijarro et *al.,* 2006). The increases in autumn precipitation over Syria found in this study should affect the volume of freshwater input.

Conclusion

In this study, meteorological data for the period of 1955–2006 from twelve Syrian stations were taken, analyzed using Mann-Kendall's test to determine the presence of long-term trends. It was found that significant trends were positive for seven station records in SON and annual (i.e. precipitation increase). But negative trends were found for DJF and MAM records. Significant trends in precipitation are most commonly found during MAM (seven stations) and least commonly found during annual (one station). Significant trends in precipitation are most commonly found at 36-37° N latitudes, with all but two of the significant trends occurred at stations northern of 33°N.

As our region is one of the most region affected by global warming and climate change, similar studies are needed and should be updated to feed the decision makers with scientifically based information about the trend of rainfall amount and their seasonally distribution for better management of water and agriculture sectors.

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