STANDARDIZED PRECIPITATION INDEX (SPI) IN NORTH LIBYA AND CONNECTION WITH NORTH ATLANTIC OSCILLATION (NAO)

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Abstract. A detailed analysis of the SPI variability was conducted targeting nine north western and northeastern meteorological stations in Libya, which has been followed by another thorough analysis of the relationship between such SPI variability and the North Atlantic Oscillation (NAO). A long term precipitation time series spans over the period (1946-2010) has been used along with NAO index data covering the same period of study. The results of the SPI analysis revealed evident distinguish periods of drought and wet years. Stations from Zwara to Benina have experienced a prolonged spell of drought from the beginning of study period up to early eighties, where since then turned to a clear intensified period of wet years onwards. In an opposite manner, the sites of Shahat and Derna started with wet period up to late seventies and shifted to drought afterwards particularly for Shahat station. Interestingly, the long period of drought illustrated at stations from Zwara through Benina seemed favors the negative phase of NAO (NAO-) whereas wet period is associated with positive phase of NAO (NAO+) with some differences between stations. In contrast, Shahat and Derna have responded negatively to NAO in general although for coastal Derna station, fourteen consecutive wet years from 1992-2005 could be attributed to the late impact of positive NAO in that region. The outcomes of this study could indeed benefit in the proactive management plans for the already at risk sectors e.g. agriculture, water resources including groundwater withdraws and water management during severe drought periods.
Keywords: *precipitation, SPI variability, drought period, wet period, NAO+, NAO-*

Introduction

Dry periods represented by the term (drought) in the Mediterranean region are of high concern and have severe consequences on many life sectors including agriculture, natural vegetation and enhancing the probability of fire occurrence (Colombaroli et al., 2007; Pausas, 2004). It also causing noticeable reductions in water availability in general but shortage in groundwater resources are the most important consequences (Cantos et al., 2000). Moreover, the Intergovernmental Panel on Climate Change (IPCC) in their recent report warned from possible intensification in the drought events during the 21st century in some areas, especially southern Europe and Mediterranean region (IPCC, 2014). Following an extended study (very recent) on the scale of drought in Europe and the Mediterranean Basin, the outcomes showed that North Africa and the Mediterranean Basin are the most vulnerable areas because of the consistent decline in their precipitation (Caloiero et al., 2018).

Although that the climate variability in the Mediterranean region is affected by different factors, the North Atlantic Oscillation (NAO) is considered as the primary atmospheric circulation mode which determines the climate in the Mediterranean region and impacts precipitation variability in the first place, air temperature, cloudiness, etc.

(Hurrel et al., 2003; Trigo et al., 2002; Hurrel and Van Loon., 1997). The NAO is traditionally defined as the normalized pressure difference between a station on the Azores and one on Iceland. The Standardized Precipitation Index (SPI) in recent years has been continuously applied for the assessment of drought intensity in many countries with different climatic characteristics (Kumar et al., 2017; Wu et al., 2006; Boken et al., 2005; Vicente-Serrano et al., 2004). The superiority of SPI over the traditional Palmer Drought Index (PDI) has been well documented in many studies, particularly when the concerned issue is the drought interpretation at different time scales (Guttman, 1998).

SPI indices have been utilized to investigate the effects of NAO on the drought conditions over the European sector of the Mediterranean Basin (Vicente-Serrano and López-Moreno, 2008). The results of their analysis showed a spatial variation in the response of drought to both phases of NAO. In northwestern Africa (Morocco), a very long precipitation data series available over the period (1901-2000) were used in a study aimed for the kind of relationship between NAO and drought events. It has been concluded that positive NAO is associated with drought period, whereas a negative NAO brings more precipitation and this behavior has dominated over all studied sites in Morocco (Karrouk, 2007). Recently, the influence of NAO on drought in the entire Mediterranean region has been investigated by (Vicente-Serrano et al., 2011). Their analysis has focused on the identification of positive and negative NAO winters, detection of anomalies of drought severity by means of Standardized Precipitation Evaporanspiration Index (SPEI). The outcomes of the analysis showed that during positive NAO, negative values of SPEI (drought) have been recorded in the Mediterranean southern Europe and northwest Africa, whereas in northeast Africa, positive SPEI values (wet) are registered. On the other hand, when NAO showed negative sign, the above results have reversed. Despite the fact that droughts are frequent in the Mediterranean region, they are not spatially uniform (López-Moreno and Vicente-Serrano, 2008; Briffa et al., 1994) and even at regional scale there are significant spatial differences (Vicente-Serrano et al., 2004).

All the above studies however have focused on the winter season, which cover the traditional months of wintertime (December-February) and in few cases (December-March). In the Mediterranean region, it has been demonstrated that the effective rainy period starts in October and ends in March as the results revealed that the amounts of precipitation during the months (October, November, March) could surpass those in winter months (Mehta and Yang, 2008; Xoplaki et al., 2004). This simply means that in the context of drought analysis in the Mediterranean, lengthening the rainy period to six months instead of three months would enforce the results and lead to prober conclusions. In addition, the findings of a late study by (Hafi and Ali, 2019) about (October-March) precipitation variability in Libya revealed contrast results with respect to the long-term precipitation trends between northwestern and northeastern sites. Upward (positive) trends in the northwest, while downward (negative) trends in the northeast. Those results have lead them to argue that whether the response of the northeastern region to the widely documented global climate change had been opposite to the response of the northwestern region or the possibility that both regions might indeed face different climates and as a result of that, their precipitation temporal viabilities could not be similar. According to the above, the main objectives of this study are as: (a) to analyze the spatiotemporal variability of dry and wet periods through (October-March) SPI variability northwestern and northeastern coastal sites in Libya;

and (b) to investigate the type of response of SPI to NAO variability during the same time scale and over the same study period.

Materials and Methods

Study area and precipitation data

The targeted area in this study is the Libyan coastal stripe from the western borders with Tunisia to the eastern borders with Egypt (*Figure 1*). The reason of selecting such area is due to the fact that the expected precipitation from October to March in Libya is only confined to the coastal land and the very close territory and very rare when the precipitation penetrates deep south of the coastal region. Nine stations were selected for this study (*Table 1*), five of them represent the northwestern region (Zwara, Tripoli, Tripoli Airport, Misurata, Sirt) and the other four represent the northeastern region (Ajdabiya, Benina Airport, Shahat and Derna).Precipitation data series belong to the nine stations were acquired from the Libyan National Meteorological center (LNMC). The initial available formats of the data were monthly totals in (mm) for October, November, December, January, February and March; which simply means that the value of precipitation of each month is in fact the summation of the daily precipitation during that month. The Drought Indices Calculator (DrinC) software package has been used in this paper as well as in several applications and studies for drought assessment and monitoring, mainly in arid and semi-arid areas.

***Table 1**. Meteorological stations under study.*

Station	Latitude (N)	Longitude (E)	Elevation from m.s.l. (m)	Period of observation	Total time (year)
Zwara	32◦53.0’	12◦05.0’	03	1946-2010	65
Tripoli	32◦54.0’	13◦11.0’	25	1946-2010	65
Tripoli Airport	32◦40.0’	13◦09.0’	81	1946-2010	65
Misurata	32◦19.0’	15◦03.0’	32	1946-2010	65
Sirt	31◦12.0’	16◦35.0’	13	1946-2010	65
Ajdabiya	30◦43.0’	20◦10.0’	-5.0	1947-2010	64
Benina Airport	32◦05.0’	20◦16.0’	122.0	1946-2010	65
Shahat	32◦49.0’	21◦51.0’	581.0	1946-2010	65
Derna	32◦47.0’	22◦35.0’	11.0	1946-2010	65

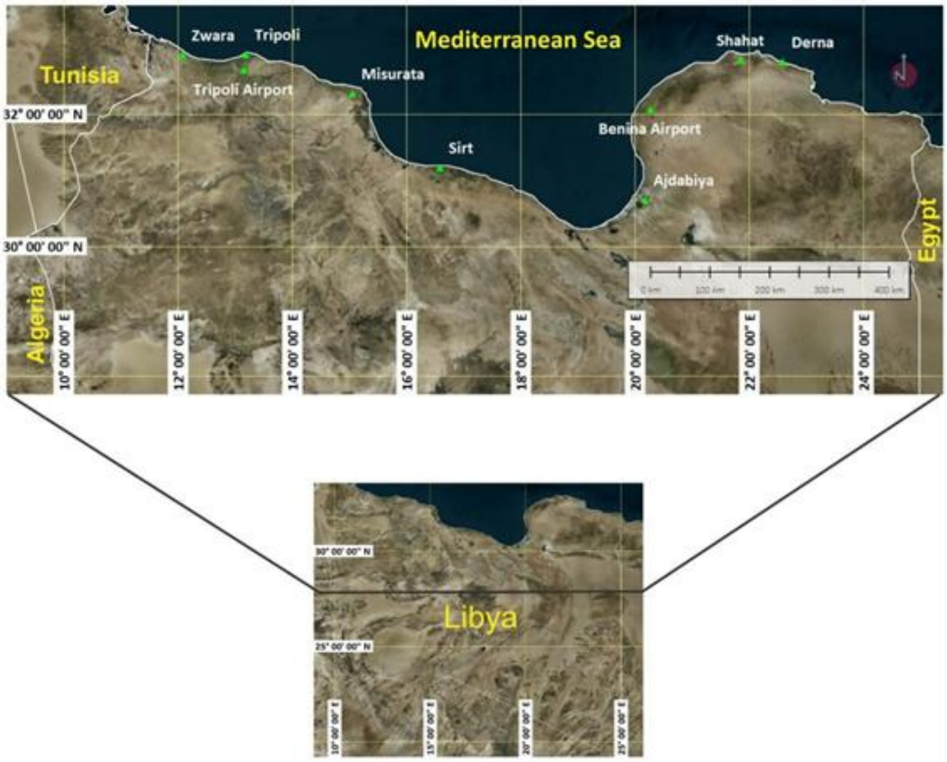

Figure 1. *Geographical positions of the northwestern and northeastern stations on the map of Libya.*

Data homogeneity

Undoubtedly, a beneficial climate researches in general require reliable observational data. Many types of disturbances can cause apparent changes in long-term climatological time series, which may distort the true climatic signal. Changes in the instrumentations, changes in observation techniques, movement of stations to new locations, environmental changes are familiar factors, which might cause breaks in the homogeneity of time series. Within the process of constructing reliable long-term data sets from original climate observations, homogenization of time series is widely recognized as a vital and priority step (Tuomenvirta, 2002). The precipitation data series that have been used in this paper are exactly the same data series used by Hafi (2016) as well as Hafi and Ali (2019). Therefore, the results of the homogeneity tests carried out in both studies have been recalled. The homogeneity of the precipitation time series for all stations was assessed by applying three different tests at a 1% significance level: The standard Normal Homogeneity Test (SNHT) (Alexandersson, 1986), The Pettitt Test (Pettit, 1979) and The Buishand Range test (Buishand, 1982).

Results of the homogeneity tests at 1% significance level showed that, the series are sufficiently homogeneous and certainly can be used for the precipitation analysis. As the focus of this study has been on the lengthened rainy wet period (October-March), the monthly totals of all these six months have been added to each other and therefore, the final precipitation value after the summation process is the total precipitation amount during the period (October-March). The above procedure however, was repeated for every year in the study period starting from 1946 up to 2010 and as a result, the resultant time series has been deployed for the calculation of SPI at every station.

Standardized Precipitation Index (SPI)

The standardized Precipitation Index was initially, modified and presented by McKee et al. (1993). It is widely accepted and used throughout the world in both drought monitoring and drought analysis because it is normalized to a location and is normalized in time. At any geographical location, the long-term precipitation data series is required for SPI calculation. Such long-term precipitation data series is fitted to a probability distribution, which after words transformed into normal distribution so that at any location the mean SPI is zero (Edwards and McKee, 1997). If SPI value is greater than zero i.e. (positive value), it means that the recorded precipitation is more than the median precipitation, whereas negative SPI value indicates that the recorded precipitation is less than median precipitation. It is worth mention that SPI values are normalized and therefore dryer and wetter climates can be represented in the same way. The mathematical and statistical procedures performed to calculate SPI in this study conform and goes in the same manner with those presented by Tigkas et al. (2013).In addition, SPI calculation can be performed through the following equation as recommended by Saighi (2005), Vicente-Serrano et al. (2004) and McKee et al. (1993):

$$SPI = \frac{Pi - m}{\sigma} \quad \text{Eq. (1)}$$

Where, Pi is the precipitation of year i, m is the long-term mean annual precipitation and σ is the standard deviation. It is important to note that SPI is a dimensionless index where negative values indicate drought and positive values indicate wet conditions. In order to differentiate between dry and wet climates as well as their scales (McKee et al., 1993) used the classification system shown in the SPI value table below (*Table 2*) to define drought intensities resulting from the SPI. They also defined the criteria for a drought event for any of the timescales. A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less.

Table 2. *Classification of drought conditions according to the SPI.*

SPI values	Classification
2.0 or more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
0.0 to 0.99	Normal condition -wet
0.0 to -0.99	Normal condition -dry
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 or less	Extremely dry

North Atlantic Oscillation Index (NAOI)

In order to investigate the noticeable effect of the large scale tele-connection NAO phenomenon on below normal (drought) and above normal (wet) events of precipitation during the selected period (October-March),a composite procedure by means of the selection of NAO indices over the same time period has been applied. Therefore, in this study (October-March) NAO indices were calculated from the difference between the standardized pressure anomalies measured at Gibraltar (south of Spain) and Reykjavík (Iceland) stations. It is important to mention, that many studies used different stations rather than the mentioned above but the advantage of using Gibraltar and Reykjavik stations has been discussed in detail by Jones et al. (1997). They noted that station Gibraltar seems to be better represent the southern part of the NAO dipole than other commonly used stations, such as Lisbon, Ponta Delgada and others in the Azores. The NAO indices used in this paper have been compiled from the Climate Research Unit (CRU) for each year is used in the NAO index time series afterward. As the main aim of this study is to investigate the patterns in the long scale (Decadal) variability of both SPI and NAO rather than the annual one, a convenient and helpful processing technique has been applied. Ten-year moving averages of SPI and NAO were estimated by first calculating the moving averages of both precipitation values and NAO indices and then normalizing them (Abou Zakhem and Kattaa, 2016; Jones et al., 1986). The latter step however, allows the calculation of SPI. The final two variables i.e. SPI (10-year moving average) and NAO (10-year moving average).were then utilized in the analysis process.

Results and Discussion

SPI variability analysis

Results of the analysis of the 10-year moving averages SPI values together with their polynomial line (3^{rd} degree) that characterizes their long-term trend are illustrated in *Figure 2* for precipitation in northwestern region and in Figure 3 for precipitation in northeastern region. Long dry and wet periods can clearly be identified among all sites with some noticeable differences between certain stations in terms of the patterns of variability, SPI intensity as well as the timing (beginning and ending) of both periods. Based on McKee et al. (1993), if the SPI value has continuously showed an intensity of -1 or less, it would be considered as a drought event. It can be noticed from *Figure 2(A)* which, begins with the far northwestern site of Zwara that since the early years of the study period, the SPI values have experienced a prolonged spell of decline (drought) through the year 1975. Despite the short interruption of a return to normality or slightly above normality of few years within such dry period, sixteen consecutive dry years (1960-1975) were extracted from SPI calculation at Zwara site so that ten years are classified moderately dry and three years are severely dry ($-1.5 \geq SPI \geq -1.99$). From the year 1976 up to 1996 the site was subject to an elongated wet period (twenty consecutive years of positive SPI) as fifteen of them are certainly considered moderately wet events ($1.0 \leq SPI \leq 1.49$) but the years 1988, 1990, 1991 and 1992 are categorized as very wet years ($1.5 \leq SPI \leq 1.99$) (refer to the *Table 2*). Since the year 1997, however the site has suffered a clear SPI decline although it varies from year to year between near to normality and slight dry events. The long-term trend line illustrates the division between the time duration of dry and wet periods.

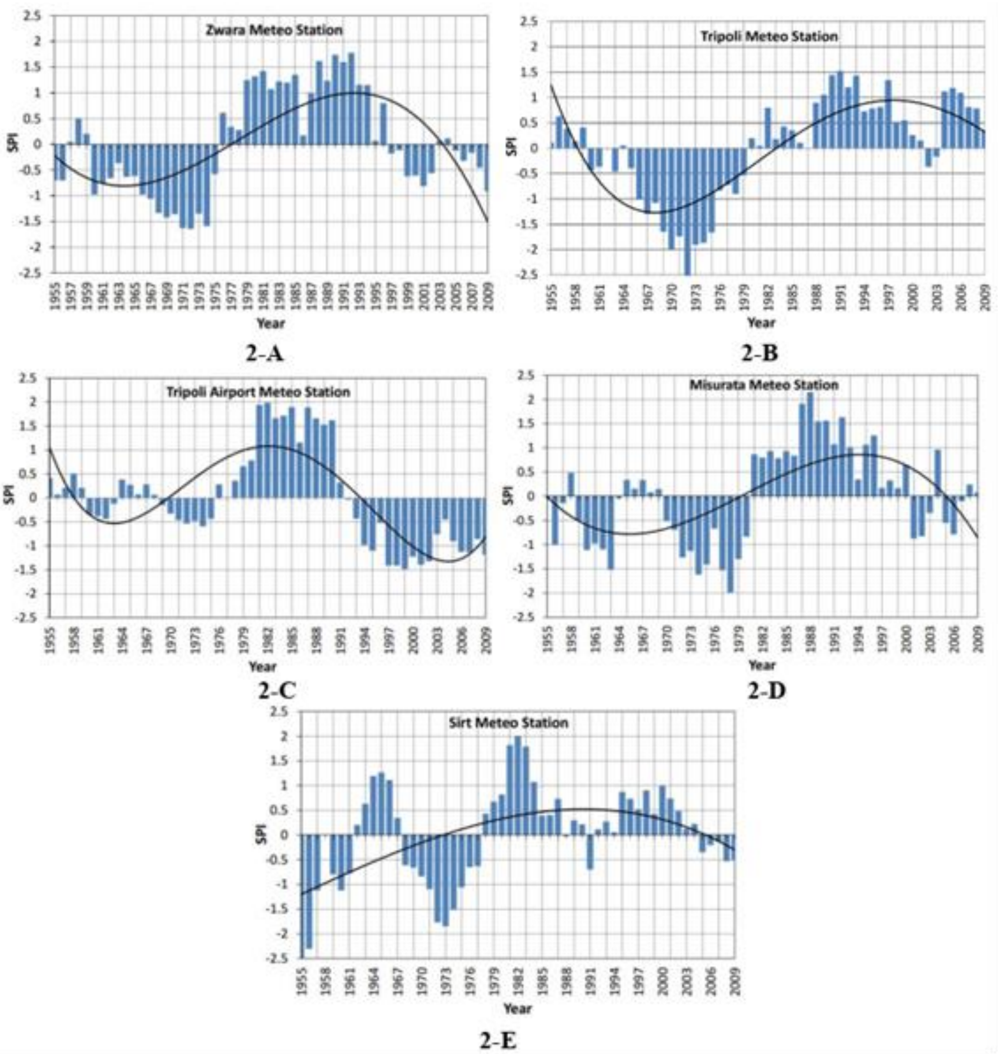

Figure 2. *Standardized Precipitation Index (SPI) variability for the northwestern sites of Libya.*

With respect to Tripoli and Tripoli Airport sites *(Figure 2 (B) and (C)*, the decline in SPI values during the long period (1960-1979) and the gradual intensification throughout those years particularly in Tripoli site is clearly evident. In late sixties and early seventies the drought has become severe with the years 1970, 1972, 1973 and 1974 were extremely dry (SPI $\leq$ - 2.0). No need to mention the slight wet characteristic of the first four years at both sites. Compared to Tripoli, the situation has been different in Tripoli Airport in terms of the drought pattern and drought intensity. Minor negative SPI values lies within the category (0 to -0.5) which in fact express the near normality condition. In addition, during this supposedly dry period, a cutoff of five wet years from 1964 to 1968 has been recorded in Tripoli Airport site although it was very slight wet. The short duration and weak decline of SPI values in Tripoli Airport compared to the lengthen and more intense SPI values in Tripoli is clearly presented by means of the long term trend lines for both sites. Since the year 1976 for Tripoli Airport and 1980 for Tripoli, the two sites were exposed to a noticeable wet period, which lasted for fifteen years with respect to Tripoli Airport but continued up to the last year of study period for Tripoli. Among the fifteen wet years in Tripoli Airport site, at least eleven are classified as very wet whereas the years 1981, 1982, 1985 and 1987 are extremely wet. This continuation of the reasonably wet events through the last year at Tripoli has been contrasted at Tripoli Airport site as after 1992 all SPI values have been negative and most of the years are categorized drought events. Again, the polynomial trend lines concerning the SPI variability in both sites clearly illustrate such contrasting response.

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For the northeastern sites starting with Ajdabiya, it is evident from *Figure 3 (A)* that the study time series has been evenly divided into two dry and wet periods, respectively. The dry period includes twenty-five consecutive years most of them are reasonably dry or considered as dry events and few are severely dry. From the year 1983 onwards, positive SPI values were distributed over another twenty-five consecutive years marking, the dominance of a remarkable wet period. During this wet period, the SPI values have positively progressed since the late nineties and therefore the precipitation conditions for those years have been categorized very wet and in some years extremely wet.

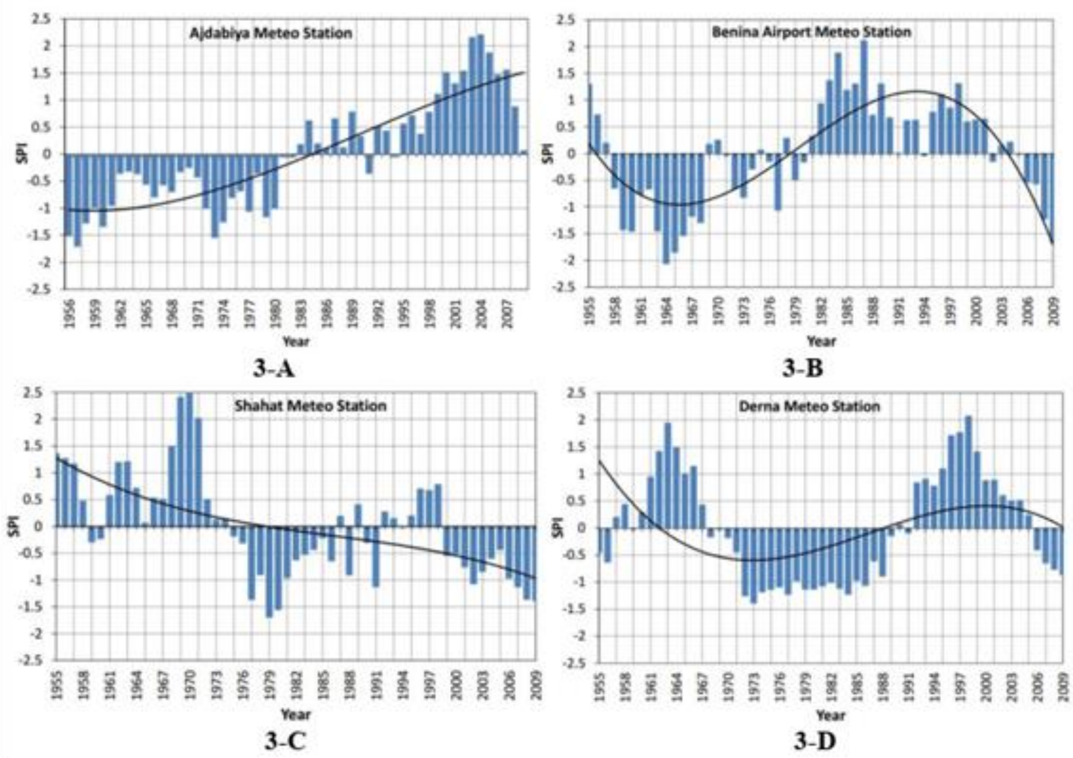


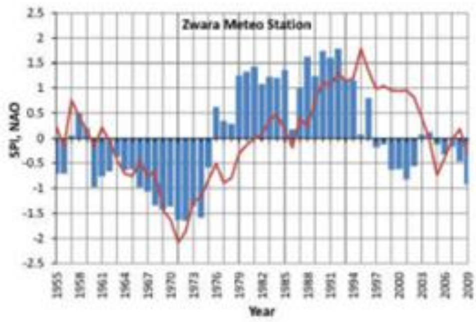
Figure 3. *Standardized Precipitation Index (SPI) variability for the northeastern sites of Libya.*

At Benina Airport site *(Figure 3 (B)*, apart from the first three wet years, eleven consecutive dry years from 1958 to 1968 are evident with two of them are moderately dry and six are classified as severely dry. After the year1968, a short interruption of three years of return to normality and very slight wet followed by a continuation of dry years through 1980. Since the year 1981 however, a noticeable shift towards a significant wet period up to 2004 covering about twenty consecutive years followed by negative SPI values during the very last years of study period. It is interesting to notice the more intense SPI values during the period 1981-1990, which includes moderately wet years ($1.0 \leq SPI \leq 1.49$) and two extremely wet years. i.e. 1984, 1987 with an abundant precipitation as ($SPI \geq 2.0$), (refer to *Table 2*).For the two remaining sites of the northeastern region i.e. Shahat and Derna, the SPI variability pattern seemed remarkably different from the previously presented sites. Instead of commencing with a clear spell of dry years similar to the other sites, an elongated period of noticeably intense positive SPI prevailed up to late seventies with more SPI strengthening and duration spotted at Shahat site. Despite the fact that most of the years were moderately wet according to their SPI values, the three consecutive years 1969, 1970 and 1971have been extremely wet as their SPI showed (+2.4), (+2.7) and (+2.1), respectively.

Since the year 1975 through 1991 for Shahat site (Fig.3-C) and also from year 1970 up to 1991 for Derna site *(Figure 3 (D)*, SPI suffered a continuous decline (negative values) which have been relatively intense during the first five years for Shahat but uniform and stable around the moderately drought condition for Derna. Between 1992 and 1998, a spell of normal to slight wet condition has been spotted at Shahat and after which the drought period continued dramatically with an evident SPI intensification during late years of the study period. With respect to Derna site however, in a dissimilar manner to what happened at Shahat, the shift towards wet period after the year 1992 showed stronger positive SPI values over a longer period (1992-2005) marking fourteen consecutive wet years. Another SPI decline has been noticed during the last four years though it is short and slight one. The decline of the long term trend line for Shahat site since year 1980 and its incline before that and also the lengthen decline of Derna's trend line up to the year 1990and very slight incline just after is a clear evidence of the contrasting SPI analysis results of these two sites compared to others. The latter results of this study regarding Shahat and Derna sites are profoundly consistent with the findings of Abou Zakhem and Kattaa (2016) that studied the drought characteristics in Damascus meteoric station using SPI and compared that with Cyprus.

SPI and NAO connection

Due to the fact that both SPI and NAO indexes are standardized variables, it was beneficial to put them on the same scale which enables tracing the type of variability of both variables year by year. It is clear from *Figures 4 (A)* to *Figure 4 (E)* the decline in SPI values that was well demonstrated previously where started in the beginning of study period through early 80s at the sites from Zwara to Sirt has been associated with an evident decline in NAO index. The more intense negative sign of NAO lead to more drought years. Within such long period of continues decline, it is interesting to notice that as an example for Tripoli the spell of the consecutive driest years 1969-1974with SPI values (-1.6, -2.0, -1.7, -2.5, -1.9, -1.9) has matched the same spell of years with the largest negative phase of NAO (-1.4, -1.6, -2.1, -1.9, -1.2, -1.2), respectively. It is important to mention that the remarkable continuous rise of NAO index from 1980 through about 2002 was associated with a noticeable rise in SPI values. As a result, long periods of very wet years prevailed throughout those northwestern sites. For Tripoli Airport however, the positive SPI response to NAO+ has persisted only up to 1991 followed by a long period of intense negative SPI (drought condition).



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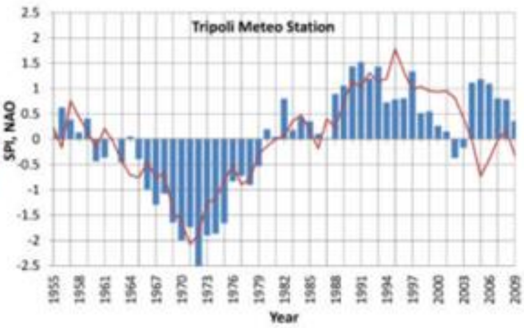

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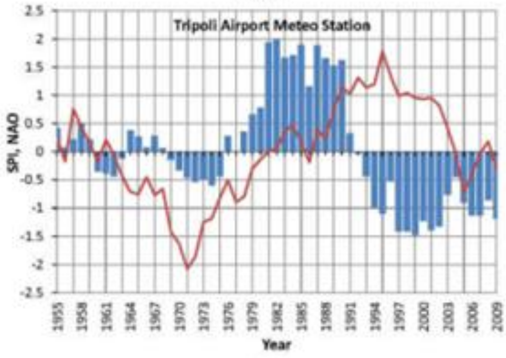

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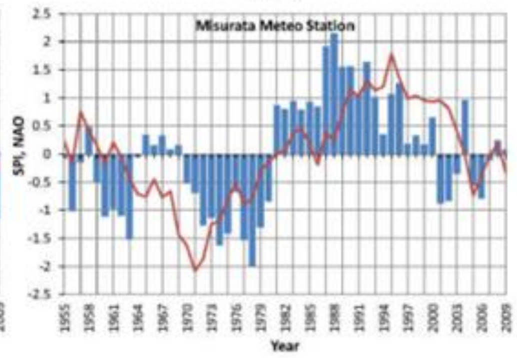

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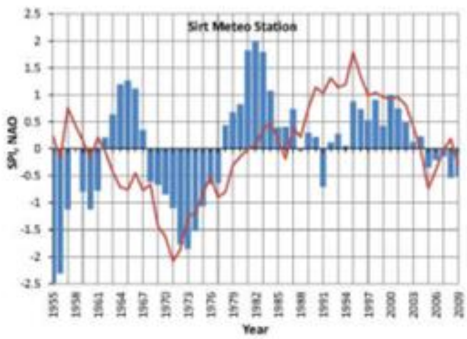

4-E

Figure 4. *10-years moving averages SPI for the northwestern sites of Libya; the thick red line is the 10-years moving average of NAO.*

The latter contrast results concerning Tripoli Airport, which is situated at approximately 45 km south of Tripoli coast, could be attributed to the variable positioning of the Azores high-pressure. The eastern sector of the Azores high pressure is usually considered as the main corridor that brings weather disturbances including precipitation. However, the inland depth of such precipitation depends mainly on the positioning of the eastern sector in particular which changes the airflow from meridional to zonal and vice versa. The meridional flow allows precipitation to penetrate deeply in land (usually above normal precipitation in Tripoli Airport) whereas during zonal flow, precipitation is confined only to the very limited coastal line. For the eastern sites of Ajdabiya and Benina *(Figure 5 (A)* and *Figure 5 (B)*, similar relationship is revealed between SPI and NAO index although that the driest years have been noticed earlier compared to the northwestern sites i.e. in the early stages of NAO declining. However, the evident drought periods for the two sites have undoubtedly accompanied the negative phase of NAO. Since 1971 and up to approximately1980 a noticeable sharp incline in the NAO index has been spotted and was associated with a gradual increase of SPI towards positive values indicating the decrease of drought conditions and return to normality for both variables.

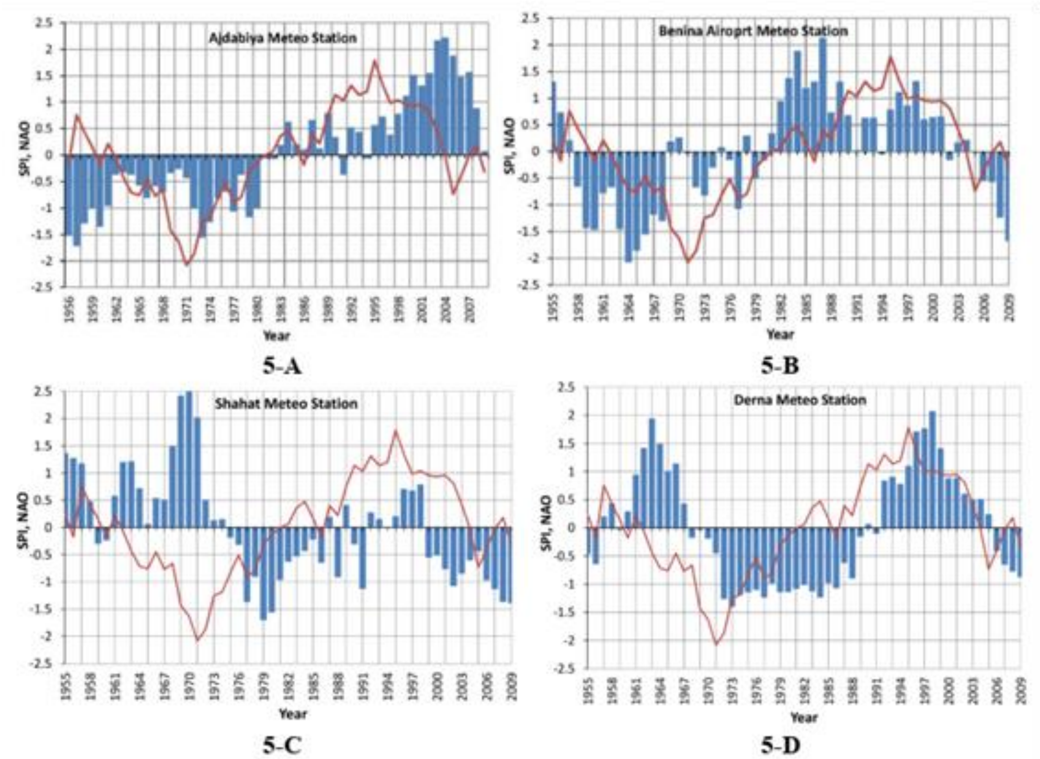

Figure 5. *10-years moving averages SPI variability for the northeastern sites of Libya, the thick red line is the 10-years moving average of NAO.*

With respect to the two remaining, northeastern sites i.e. Shahat and Derna *(Figure 5 (C)* and *Figure 5 (D)* the analysis of SPI and NAO relationship has revealed remarkably different results compared to other sites. The noticeable descend of NAO since the beginning of study period through 1971 has been oppositely responded by a dramatic increase in SPI values. The wettest consecutive years on data series record for Shahat site have been noticed over the years 1968 to 1971with the extremely wet 1969, 1970 and 1971 years showed very intense SPI, +2.4, +2.7 and 2.0, respectively. During those three wet years, NAO showed its lowest negative phase with index values (-1.4, -1.6, -2.1).

The response of Derna site to the NAO has been to a large extent similar to that of Shahat with slight differences in both SPI intensity and duration. Another negative response has been spotted with respect to SPI values for both sites during the well documented sharp NAO rising period since 1971. Concerning Shahat, except for the short wet interruption during years (1992-1998), a general dominance of drought years is clearly identified up to the last year of the study period. Consistent with Shahat, a very long period of consecutive drought years has prevailed from 1971 through 1991 at Derna site in response to the NAO but after that a noticeable shift towards a long spell of wet years similar in the timing to that of Shahat but different in terms of SPI strength and duration. Fourteen consecutive wet years between 1992 and 2005, whereby afterwards returned to the drought in the last four years of study period. The switch on of the late precipitation which varies recognizably between Shahat and Derna indicates the possibility of the role of the local effect which usually a common characteristic even within close regional scale. In addition, the evident increase of NAO since 1992 towards its maximum positive phase might have played certain role in shifting the situation from dry to wet particularly in the coastal Derna site.

Conclusion

The SPI variability analysis has revealed the presence of drought periods as well as wet periods at the studied sites in Libya although SPI intensity and duration differ from one site to the other. The closer the sites to each other the more consistent and symmetric is their SPI temporal variability. Sites from Zwara in the far northwest of Libya through Benina in the northeast have all witnessed long periods of consecutive dry years extended from the beginning of the time series until late 70s and early years of 80s at some sites. Since then however, remarkable lengthened wet periods have been detected at most of the sites with consecutive very wet and even extremely wet years have been recorded. Moreover, the SPI variability analysis for both Shahat and Derna sites have showed opposite patterns to other sites. The outcomes of this study agree largely with the findings of López-Moreno and Vicente-Serrano (2008) as well as Briffa et al. (1994) for the slight spatially non-uniformity between close sites and confirm the results of Vicente-Serrano et al. (2004) for the regional significant differences with respect to SPI variability between northwestern and northeastern sites. Most importantly, our results could give a proper interpretation to the contrast or opposite results obtained by Hafi and Ali (2019) between north western and northeastern sites in Libya with respect to (October-March) long-term precipitation trends. In particular, provide a probable answer to the question, which has been raised about the possibility that the further most northeastern region is indeed experiencing another climate regime mostly from the eastern Mediterranean in addition to that from the western Mediterranean.

With respect to the NAO impact in SPI variability, it has appeared that sites from Zwara in the far northwest up to Benina in northeast are positively related to NAO. Whereas, the two northeastern sites, Derna and Shahat are negatively related to NAO although the SPI variability percentage which can be explained by NAO variation is beyond the scope of this study. The positive connection means simply that the continuous decline of NAO Index (negative phase) would lead to a matching decline in precipitation (negative SPI) whereas the rise of NAO index to its recognizable positive phase would be associated with SPI increase and therefore more precipitation is expected. Therefore, if the NAO signal can be predicted accurately in advance, which is still a debatable issue, the direction of precipitation in major part of north Libya can also be approximated in advance. These results are of great importance to many vital sectors in Libya e.g. Agriculture, water resourcing and water management. The advance prediction of drought conditions in particular, enable decision makers to take mitigation actions and to adopt a sustainable proactive management plan during such frequent severe droughts.

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Conflict of interest

The authors of this paper confirm that there is no conflict of interest. They have fully contributed to its development and drafting.

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