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THE VARIABILITY OF WINTERTIME PRECIPITATION IN THE NORTHERN COAST OF EGYPT AND ITS RELATIONSHIP WITH THE NORTH ATLANTIC OSCILLATION

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ABSTRACT - Apart from the northern coast, most of Egypt is desert. However, the northern coastal region experiences some precipitation mainly during winter. We investigate the variability of wintertime (December, January and February) precipitation in North Egypt during the 39-yr interval 1961-1999 and its relationship with the North Atlantic Oscillation during autumn and winter. We have used the time series formed of winter season ranked precipitation to study the variability. Also, the correlation coefficient technique is used to study the relationship between precipitation and North Atlantic Oscillation. Precipitation varies dramatically from winter to winter, particularly at Alexandria. A highly significant and positive correlation is found between precipitation along the northern coast of Egypt and the North Atlantic Oscillation for winter rather than autumn for the stations El Salum, Matruh and Port Said.

1- INTRODUCTION

The northern coast of Egypt experiences precipitation mainly in winter (December, January, and February). The largest precipitation amounts (annual total larger than 250mm) were found in Alexandria and Matruh during the last four decades. The northern coastal region has experienced widely varying annual precipitation. In 1970, most of the northern region received only about 20% of the normal precipitation, while other years in the 1980s precipitation totals reached 150% of the main in Matruh. In 1960's Alexandria and Port Said received approximately 200% of average precipitation. Fluctuations of this magnitude over such a large region constitute one of the dominant forms of climate variability in Egypt. The dramatic swings in annual precipitation in the northern coast of Egypt affect its residents through flood damage in heavy rain years and water rationing in drought years. This region is considered an agricultural promising region in Egypt. Generally, on a longer timescale, years of significantly below-normal precipitation intensify the on-going competition between the agricultural, industrial, and domestic users of the scare water resources at the northern coast.

The normal atmospheric situation over the North Atlantic Ocean has surface westerlies blowing across the ocean at about 40 ^{O}N between the surface expression of the Icelandic low and the Azores high, with the most intense westerlies existing during the winter season. On times scales ranging from monthly to interdecadally, there is an oscillation of the strength of these pressure features which can be conveniently measured by the difference in surface pressure between the Azores and Iceland. The state of this North Atlantic Oscillation (NAO) is positive when the Azores high is strong and the Icelandic low is deep and negative when reversed, as shown in Fig. (1a, 1b), Dickson (1996). Both phases are associated with changes in the intensity and location of the North Atlantic westerlies, jet stream and storm tracks, and with resulting changes in temperature and precipitation patterns. The positive phase of the NAO is mostly easily characterized during the winter and has the following effects;

1-Stronger westerlies across the Atlantic extending further north towards the British Isles and pointing towards northern Europe,

2- A more intense storm track roughly steered by the displaced westerlies,

3- Stronger upwelling off the coast of Portugal and North-western Africa due to the southerlies accompanying the intensified Azores high,

4- Stronger (easterly) trades off the coast of Africa into the subtropical Atlantic,

5- Wet anomalies over the eastern US coast extending across the Atlantic into Scandinavia and northern Siberia,
6- Dry anomalies over the Labrador Sea and over southern Europe and the Mediterranean region,
7- Wet anomalies over northern Africa extending eastward into the Arabian Sea,
opposite patterns of temperature, precipitation, and wind are usually observed with the negative phase of the NAO, Sarachik and Alverson (2000).

Previous investigations of the seasonal-meantime-scale mechanism, that influence the northern coast of Egypt wintertime precipitation focused on the role of the anticyclonic blocking systems that persist over Europe, El-Fandy (1946), Hafez (1995, 1999a). It is envisioned in these studies that the interaction between the pressure systems over western and eastern Europe can influence the planetary–scale atmospheric circulation and affect the cyclogensis in the Mediterranean. Climate variability associated with changes in intensity and location of storm tracks has not been studied to as great an extent as that associated with low-frequency components of the circulation such as standing waves, van Loon and Williams (1976), Shabbar et al. (1990); blocking flows, Rex (1951), Namias (1964, 1978), Dickson and Namias (1976), Lejenas (1989), and Hafez (1999a), and atmospheric teleconection patterns. In the lower troposphere over the North Atlantic, the North Atlantic Oscillation (NAO) is typically regarded as the primary regional teleconnection and is linked to observed climatological and oceanographic variability, van Loon and Rogers (1978), Lamb and Peppler (1987), Moses et al. (1987), Mann and Drinkwater (1994), Hurrell (1995) and more recently, Mitchell and Blier (1997). The North Atlantic storms track variability is associated to the North Atlantic Oscillation and climate variability of northern Europe. In general, climatic fluctuations that occur on the North Atlantic influence weather and climate over the Mediterranean, Rogers (1997).

The purpose of this paper is 1) to study the variability of wintertime precipitation along the north coast of Egypt; 2) to show how it is related to the north Atlantic oscillation; 3) to relate it to regional climate variability in the North Atlantic.

Characteristics of the large- scale North Atlantic Oscillation (NAO) in autumn and winter seasons, and wintertime precipitation in the northern coast of Egypt (El Salum, Matruh, Alexandria, and Port Said) are considered including the most extreme wet and dry winter seasons through regression analysis.

The organization of the paper is as follows. The data and analysis methods employed are described in section 2. Documentation of the seasonal wintertime precipitation variability that influences the northern coast of Egypt is given section 3. The relationship between this variability and the north Atlantic oscillation is examined in section 4. The results are discussed in section 5.

2- DATA AND ANAYSIS METHODS

The Egyptian Meteorological Authority (EMA) data employed in this study comprise monthly precipitation totals for selected four stations in the northern coast of Egypt for the period from December 1960 to February 1999 (except El Salum to 1996), (see Table 1). The source of monthly North Atlantic Oscillation index (NAOI) data is the Climate Prediction Center, National Oceanic and Atmospheric Administration, NOAA. Anomalies for the wintertime precipitation are calculated during the period of study 1960-1999. Seasonal anomalies for the precipitation are calculated as the average of the anomalies for December, January and February, beginning December of 1960 and ending with February 1999. For studying precipitation variability, we have used the time series as percentile – ranked precipitation, that is, the percentile index (0-100). The northern coast of Egypt, December-February (DJF) seasonal precipitation variability is primarily captured by percentile ranked method. We follow the suggestions of Meisner (1976) and Repelowski and Halpert (1986), to represent the seasonal precipitation data at each station as percentile ranks. For each winter, the entire $n - year$ record of precipitation data is ranked from 1, for the lowest precipitation amount, to n for the maximum precipitation amount; these ranked precipitation amounts are then normalized by the number of years of record and multiplied by 100. 50 are then subtracted from the normalized ranked value (*x*). Then we get an Index value of variability (I) where $I = x - 50$. If index I is zero, this means that no variability occurred. When $0 \rangle I \rangle -50$ this means that there is negative variability and the precipitation less than normal. When $50 \rangle I \rangle 0$ this means that the variability is positive and precipitation exceeds the normal. The resulting percentile ranks index *I* is calculated for station, in order to facilitate the interpretation of precipitation patterns in the regimes. For wet seasons $50 \geq I > 25$, while $-25 \rangle I \geq -50$ for dry seasons.

The simple method correlation coefficient analysis, introduced by Mood et al. (1974) have also been used in the present paper to study the relationship between the NAOI in Autumn and winter, and wintertime precipitation anomalies in the Egyptian northern coast.

3- WINTERTIME PRECIPITATION VARIABILITY

For El Salum station, the precipitation amount varies dramatically from winter to winter form 1961 until 1966. After that, it becomes less than the normal value until 1973 except for 1971. From 1977 to 1996 it is clear that precipitation varies dramatically again. However, 1977- winter season is the driest winter, meanwhile 1993 winter represents the wettest one during the period of study. As it is shown from Fig. 2a. and Table2. 1977, 1970, 1968, 1972, and 1984 represent the driest years. The wettest years are 1993, 1978, 1964, 1995, and 1962.

Like El Salum station, Matruh precipitation, varies dramatically from 1961 to 1965. After that period, it becomes less than the normal value until 1972 except in 1968. From 1977 to 1995 it is clear that precipitation varies dramatically again. After this period the precipitation decrease on 1996, 1997, and 1998. However, 1977- winter season is the driest winter, meanwhile 1983 winter represents the wettest one during the period of study. As shown in Fig. 2b and Table 2, 1977, 1970, 1979, 1963, and 1984 represent the driest years, while the wettest years are 1983, 1978, 1993, 1989, and 1988.

Alexandria precipitation varies dramatically from winter to winter for the entire period under study. Winter seasons of 1984, 1999,1970, 1994,1992 represent the driest seasons. Meanwhile, 1965, 1969, 1993, 1983 and 1989 represent the wettest winter seasons, Fig. 2c and Table (2). This means that Alexandria have specific precipitation regime rather than El Salum and Matruh. This regime may reflect the local effects of its geographic site. Geographically, Alexandria extends as a tongue inside the Mediterranean Sea, which cause the sea breeze and generates local circulations if the Mediterranean airflow moves toward the land. As a result, it becomes a baroclinic instability region and may developed convective clouds.

On the eastern northern coast of Egypt that represents by Port Said, one can find that there is another precipitation regime. Years 1963, 1970, 1999, 1984, and 1979 are represent the driest seasons meanwhile, 1962, 1997, 1993, 1989, and 1990 represent the wettest seasons as shown in Fig. 2d and Table 2. However, it is noticed that, there exists a successive period of drought on 1968, 1969, 1970 and another successive period of floods on years 1988, 1989, and 1990, as exists in Fig. 2d. This may be due to that the precipitation in winter in the northeast coast of Egypt comes from only one type of depressions (orographic depression so called Cyprus low). Meanwhile, the precipitation in the western coast, El Salum, Matruh, and Alexandria, comes from two types of depressions. First one is the traveling depression from the Atlantic Ocean across the Mediterranean to invade the western coast. Second one, is the depressions developed in the eastern Mediterranean like Cyprus low El-Fandy (1946) and Hafez et. al. (1999b). From the above results, it is difficult to predict the variability of precipitation in the northern coast of Egypt.

4- THE RELATIONSHIP BETWEEN NORTH ATLANTIC OSCILLATIONS AND NORTHERN COAST OF EGYPT

The North Atlantic Oscillation has a large climatic influence on the North Atlantic Ocean and surrounding landmasses. The NAO came into the focus of scientific work, a number of studies considered the influence of this large scale variability pattern on local meteorological quantities such as seasonal precipitation, temperature and wind velocity, e.g. Wallace and Gutzler (1981), Deser and Blackmon (1993), Hurrell (1995), and Rogers (1990). Some of the previous studies on NAO Socioeconomic and ecological impacts were include. Luterbacher et al. (1999) have published a multiproxy derived NAO index with monthly resolution from 1675 to 1990. They show that the correlations between the many individual paleo reconstructions that are now available are not high enough to regard any one of them as definitive. From analysis of the North Atlantic Oscillation Index (NAOI) Data in winter (DJF) during the period (1960-1999), one can see that, there is an interdecadal cycle (every 5 years). The values of NAOI are found negative in the period from (1960-1970); afterwards the sign alternates between negative and positive every five years, as shown in Fig. 3b. Meanwhile, NAOI in autumn (SON) has changed from autumn to autumn during the period of study, as shown in Fig.3a. Table 3 presents the correlation coefficients between NAOI in autumn and winter seasons and wintertime precipitation in the north coast of Egypt. . A poor relationship between NAOI in autumn and wintertime precipitation in the north coast of Egypt is found, see Fig. 4a, b, c, d. and Table 3. Meanwhile, positive correlation with high significance confidence level is found between NAOI in winter and wintertime precipitation in the north coast of Egypt for most stations, Fig. 5 and Table 3. This reveals that the wintertime NAO affect the wintertime precipitation in the north coast of Egypt. This is a natural expected result as the NAO is controlling the westerly air current and the track of the travelling depressions across the Mediterranean.

5- DISCUSSION

The variability of wintertime precipitation in the northern coast of Egypt indicate to a dramatically change from winter to winter particularly at Alexandria. A highly significant and positive correlation is found between precipitation along the northern coast of Egypt and the North Atlantic Oscillation for winter rather than autumn for most of stations. However, the results show that the north coast of Egypt is characterized by two precipitation regimes. The first one exists in the western region represented by El Salum, Matruh, and Alexandria stations. This region is mainly invaded by travelling depressions across the Mediterranean area from the Atlantic Ocean. In addition to these depressions, the orographic lows, which generate near Cyprus and induced on this region. The second one is in the eastern region represented by Port Said station. The precipitation amounts of this region come mainly from the Cyprus low.

There is a high significant and positive relationship between the North Atlantic oscillation in winter and anomalies wintertime precipitation in the north coast of Egypt. Meanwhile there is a weak relationship between wintertime precipitation and NAOI in autumn. On the wettest winter season 1993, most part of the northern coast of Egypt records the maximum precipitation amounts. During this winter the NAOI has value +1.9, not the highest value. While, on 1970 (the driest winter season), the NAOI in winter has value -0.3, not the lowest value. The results encourage that there are another factors other than NAO may have considerable influence on rainfalls in the north coast of Egypt.

In general, The Middle East has a Mediterranean macroclimate, characterized by cool, wet winters and hot, dry summers. Most of the Middle East has impoverished surface and groundwater resources due to subtropical predominance of evaporation over precipitation. The variations in Middle Eastern climate are physically linked to a known mode of natural climate variability originating in the North Atlantic. During positive (high) phases of the NAO, the subtropical-subpolar winter SLP gradient is enhanced, leading to a strengthening of the Atlantic westerly low-level wind field. These mid-Atlantic westerly, in turn, become more meridional and advect warm, moist Atlantic air to the northeast, resulting in warmer, wetter conditions in Scandinavia and northern Europe and cooler, drier conditions in Greenland, the Mediterranean, and Middle East. During negative (low) phases of the NAO, the pressure gradient is weakened and Atlantic westerly assume a more zonal trajectory, bringing wetter, warmer conditions to the Mediterranean region. While the NAO reflect changes in the strength and orientation of mid-Atlantic westerly, which dictate heat and moisture flux trajectories, the NAO is also expressed in terms of distinct North Atlantic sea-surface temperature, sub-surface temperature and sea-ice extent anomalies. During the positive (high) phase of the NAO, SST's in eastern Mediterranean, and subtropical Atlantic are anomalously cold by 0.5-1°C, whereas SSTs in the North Sea and Sargasso Sea are anomalously warm by approximately the same amount. The primary origin for the NAO remains elusive but terrestrial climate signatures and associated surface and deep Atlantic oceanographic signatures suggest a dynamically coupled ocean-atmosphere phenomenon. The NAO has playing a great role in the cyclonic trajectories in the Mediterranean in winter. However, the present study shows that there is significant correlation between the North Atlantic Oscillation in winter and the variability of wintertime precipitation in the northern coast of Egypt.

Table 1. The selected stations and its characteristics.

STATION	LATITUDE	LONGITUDE	ALTITUDE
EL SALUM	**31° 32′**	**25 ° 11′**	**4 Meter above MSL**
MATRUH	**31° 20′**	**27 ° 13′**	**25**
ALEXANDRIA	**31° 17′**	**29° 57′**	**-3.4**
PORT SAID	**31° 12′**	**32° 14′**	**0.8**

Table 2. Ranked values of the normalized precipitation index in winter season that explains the largest amounts of northern coast of Egypt precipitation variability.

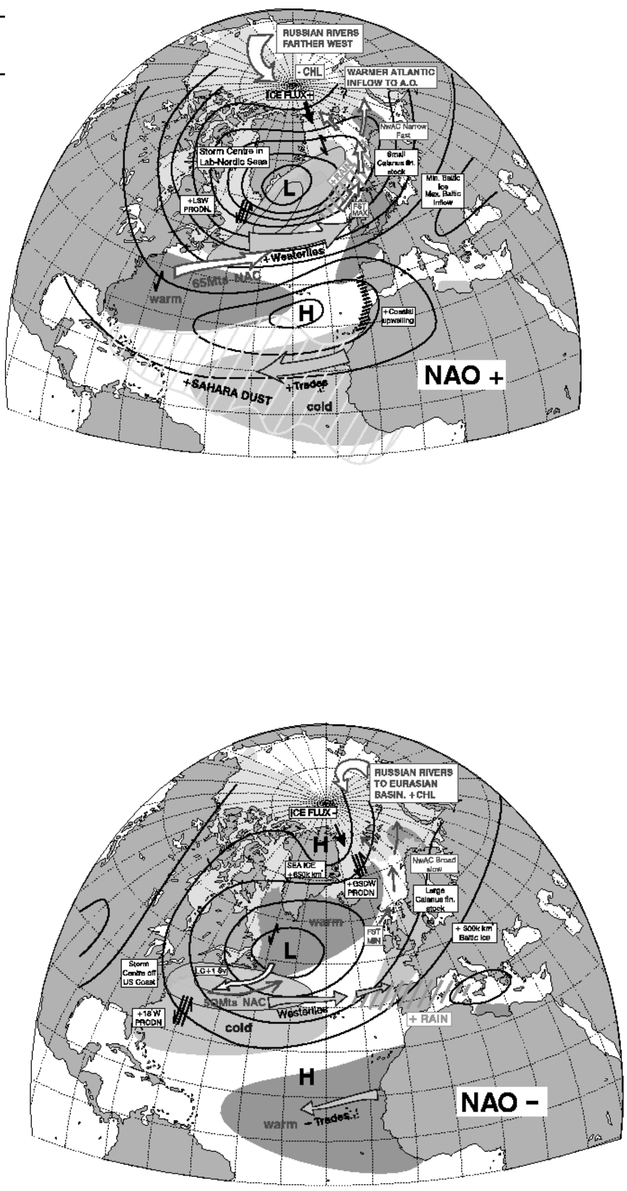
Station	EL SALUM		MATRUH		ALEXANDRIA		PORT SAID	
Rank	Index Value (I)	Year	Index Value (I)	Year	Index Value (I)	Year	Index Value (I)	Year
Driest 1	-47.2	1977	-47.3	1977	-47.3	1984	-47.3	1963
2	-44.3	1970	-45	1970	-45	1999	-45	1970
3	-41.4	1968	-42.3	1979	-42.3	1970	-42.3	1999
4	-38.6	1972	-39.8	1963	-39.8	1994	-39.8	1984
5	-35.7	1984	-37.2	1984	-37.2	1992	-37.2	1979
35	38.5	1962	39.7	1988	39.7	1989	39.7	1990
36	41.4	1995	42.3	1989	42.3	1983	42.3	1989
37	44.3	1964	44.8	1993	44.8	1993	44.8	1993
38	47.1	1978	47.4	1978	47.4	1969	47.4	1997
Wettest 39	49.5	1993	48.5	1983	48.5	1965	48.5	1962

Table 3. Correlation Coefficient between north Atlantic Oscillation Index in autumn and winter seasons and precipitation in north coast of Egypt in winter season.

STATION	AUTUMN (NAOI)	WINTER (NAOI)
El-Salum	-0.15	0.34**
Matruh	0.10	0.36**
Alexandria	0.10	0.12
Port-Said	0.05	0.24*

**** Significant at 99% confidence level**
*** Significant at 95% confidence level**

a



b

Figure 1. Schematic represents two distinguished cases , a) positive and b) negative phases of the Northern Atlantic Oscillation. (courtesy of B. Dickson, CEFAS).

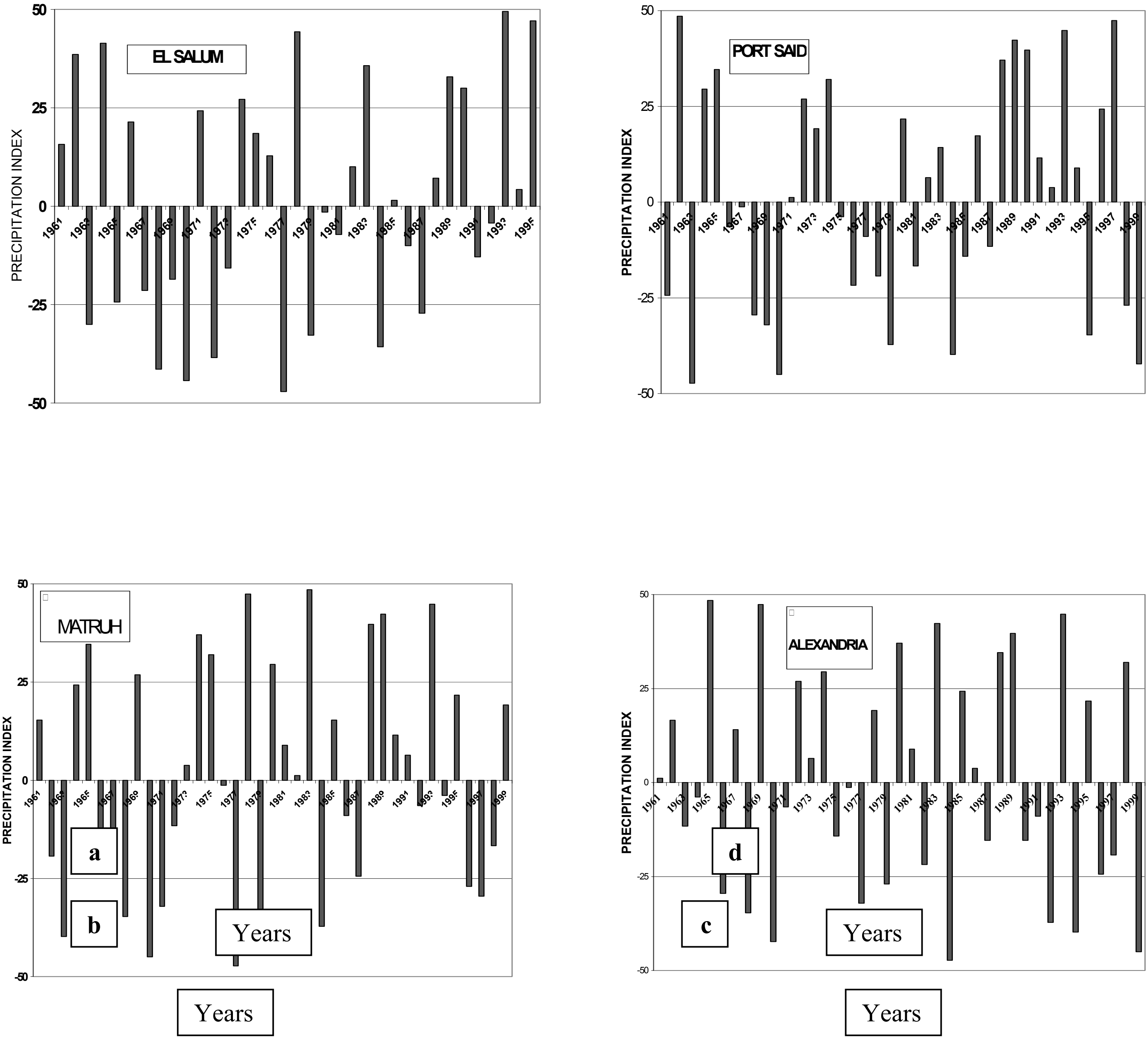
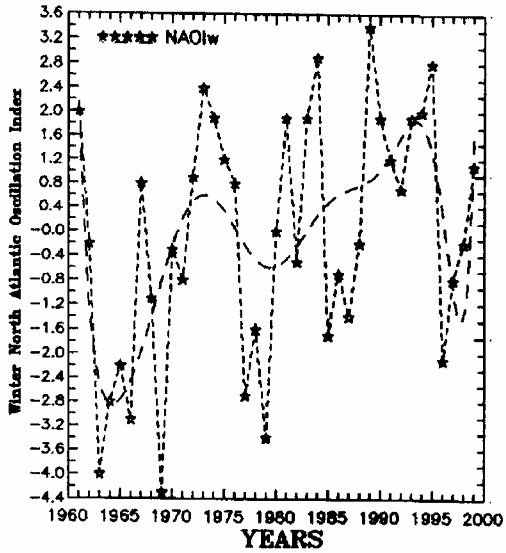


Figure 2. Represents the wintertime precipitation variability for four stations (a, b, c, and d respectively) in the northern coast of Egypt during the period (1960- 1999).

a)



b)

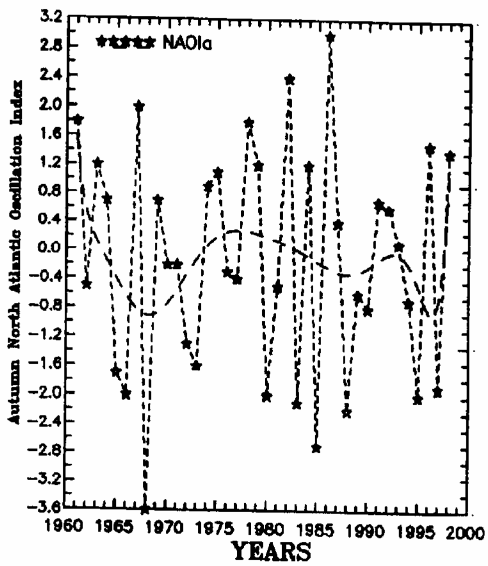


Figure 3. Represents distribution of the North Atlantic Oscillation Index a) in autumn and b) in winter seasons.

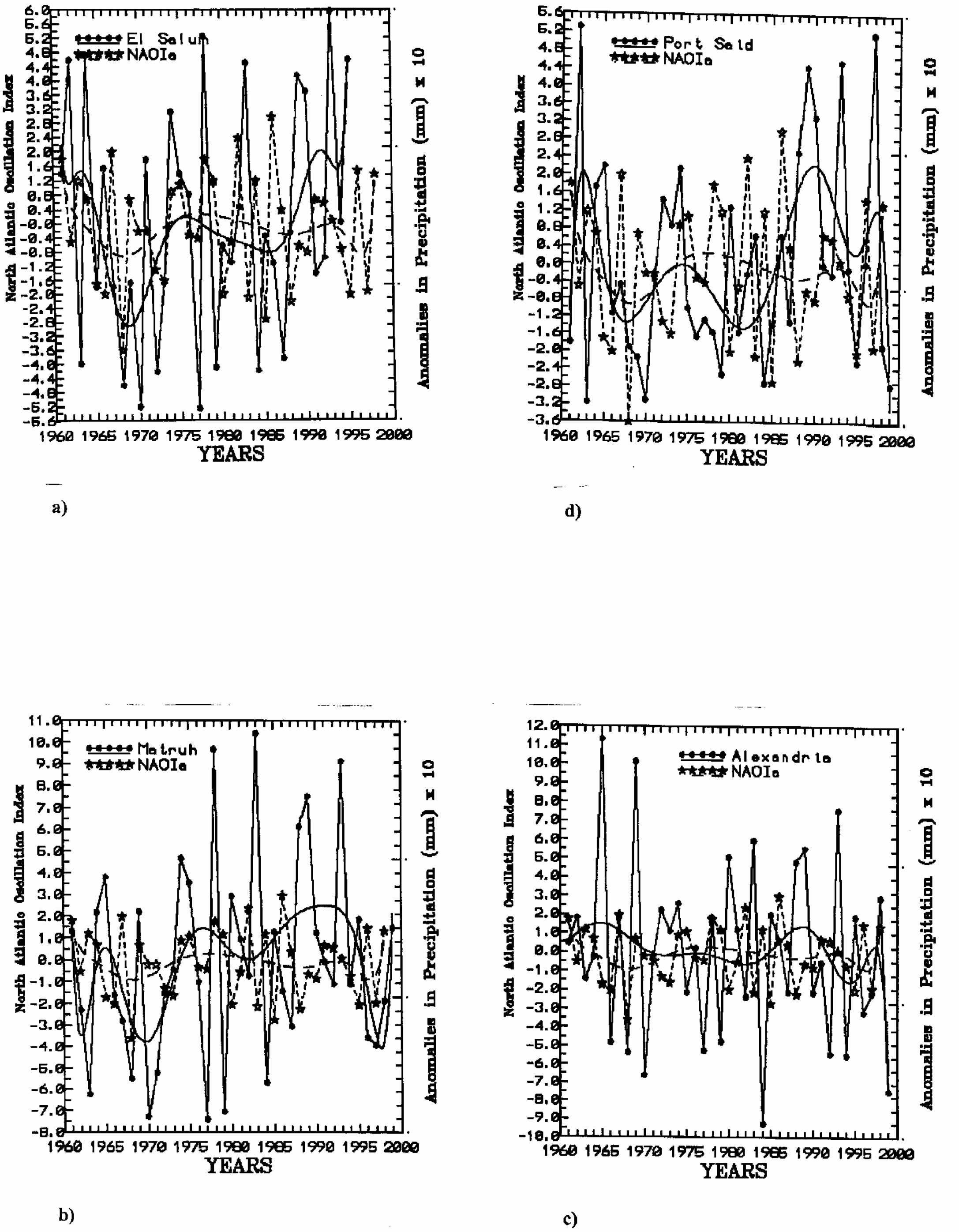


Figure 4. Fluctuations of the North Atlantic Oscillation Index in autumn and anomaly in wintertime precipitation for four stations along the north coast of Egypt a) El Salum b) Matruh c) Alexandria d) Port Said.

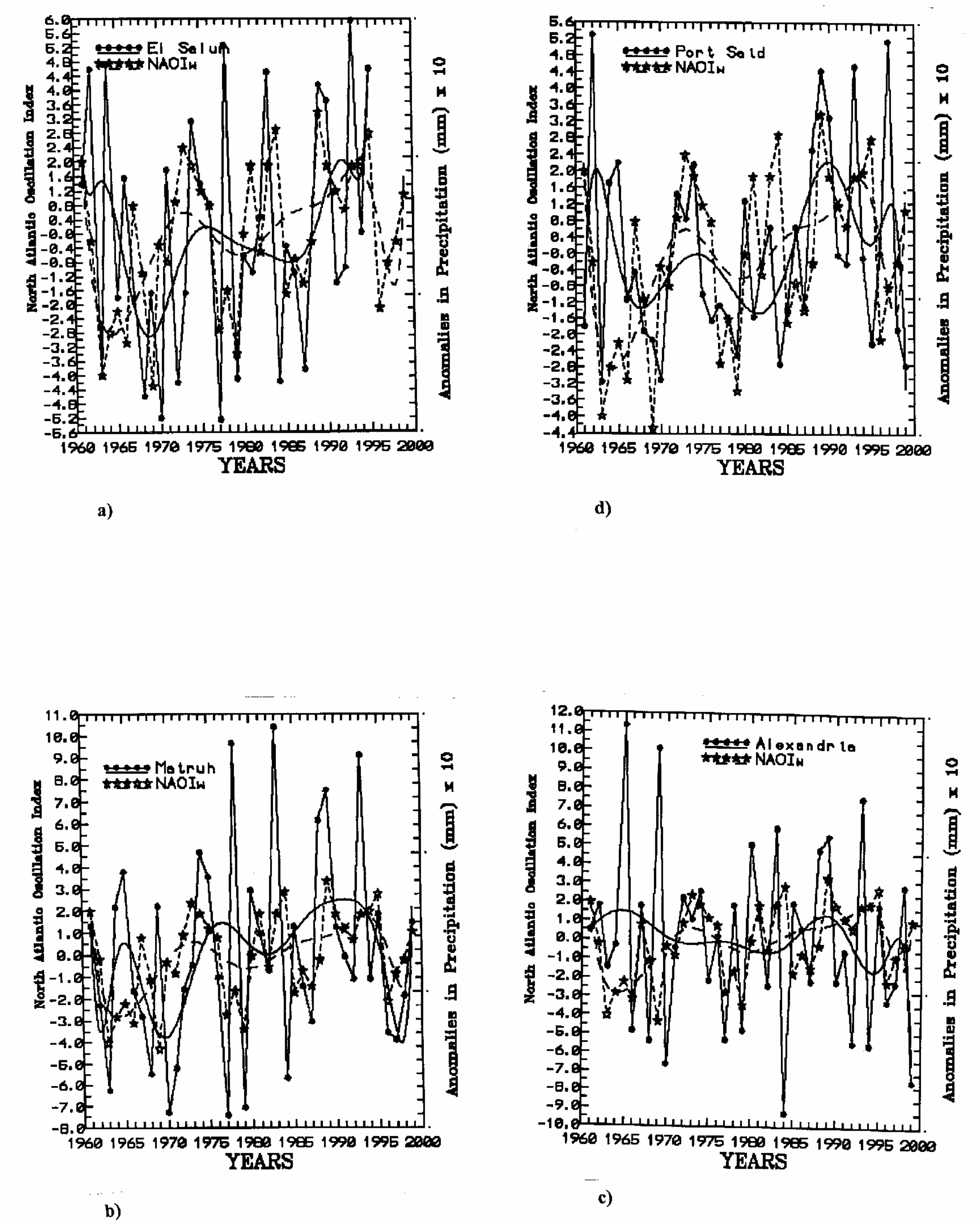


Figure 5. Fluctuations of the North Atlantic Oscillation Index in winter and anomaly in wintertime precipitation for four stations along the north coast of Egypt a) El Salum b) Matruh c) Alexandria d) Port Said.

REFERENCES

Deser, C., Blackmon, M. E., 1993: Surface climate variations over the North Atlantic Ocean during winter: 1900-1989. J. Climate, 6,1743-1753.

Dickson, R. R., and J. Namis, 1976: North America influences on the circulation and climate of the North Atlantic sector. Mon. Wea. Rev., 104, 1255-1265.

El-Fandy, M. G., 1946: Barometeric low of Cyprus. Quart. J. R. Met. Soc., 7, 291-306.

Hafez, Y. Y., 1995: Impact study concerning the effect of blocking highs persisting over eastern Europe on weather in Egypt. M. Sc. THESIS, Faculty of Scien0ce, Cairo University, Egypt.

Hafez, Y. Y., 1999a: On the characteristics of blocking highs that persist over Europe in winter. The fourth conference " Meteorology & Sustainable Development to 21st Century, 15-33, 7-9, March 1999, EMA, Egypt.

Hafez, Y. Y., El- Fandy, M. G., and Zohdy, M. M., 1999b: On the effect of blocking highs over Europe in enhancing the cyclogensis and on traveling depressions in the eastern Mediterranean. The fourth conference " Meteorology & Sustainable Development to 21 st Century, 35-46, 7-9 March 1999, EMA, Egypt.

Hurrell, J.W., 1995: Decadal trends in the North Atlantic Oscillation regional temperatures and precipitation. Science, 269, 676-679.

Lamb, P.J., and R. A. Peppler, 1987: North Atlantic Oscillation: Concept and an application. Bull. Amer. Meteor. Soc., 68, 1218-1225.

Lejenas, H., 1989: The sever winter in Europe 1941-42: The large-scale Circulation, cut-off lows, and blocking. Bull. Amer. Meteor. Soc., 70, 271-281.

Luterbacher, J., et al, 1999: Geophys. Res. Lett., 26, 2745.

Mann, K.H., and K.F. Drinkwater, 1994: Environmental influences on fish and shellfish production in the northwest Atlantic. Environ. Rev., 2, 16-32.

Meisner, B. N., 1976: A study of Hawaiian and Line Island rainfall. Rep. UHMET 76-4, Dept. Meteor., University of Hawaii, Honolulu, 82pp.

Moses, T., G. N. Kiladis, H. F. Diaz, and R. G. Barry, 1987: Characteristics and frequency of reversals in mean sea level pressure in the North Atlantic sector and their relationship to long-term temperature trends. J. Climatol., 7, 13-30.

Mitchell, T. P., and W. Blier, 1997: The variability of wintertime precipitation in the region of California. J. of Climate, 10, 2261-2276.

Namias, J., 1964: Seasonal persistence and recurrence of European blocking during 1958-60. Tellus, 6, 394-407.

--------, 1978: Multiple causes of the North American abnormal winter 1976-77. Mon. Wea. Rev., 106, 279-295.

Rex, D..F., 1951: The effect of Atlantic blocking action on European climate. Tellus, 3, 100-112.

Rogers, J.C., 1990: Patterns of low-frequency monthly sea level pressure variability (1899-1986) and Associated wave cyclone frequencies. J. Climate, 3, 1364-1379.

-------, 1997: North Atlantic storm track variability and its association to the North Atlantic oscillation and climate variability of northern Europe. J. of Climate, Vol 10, 1635-1647.

Ropelewski, C.F., and M.S. Halpert, 1986: North American precipitation and temperature patterns associated with the El Nino Southern Oscillation (ENSO). Mon. Wea. Rev., 114, 2352-2362.

Sarachik, E. S., K. Alverson, 2000: Opportunities for CLIVAR/PAGES NAO Studies. PAGES Newsletter Vol. 8, No. 1, 14-16.

Shabbar, A., K. Higuchi, and J. L. Knox, 1990: Regional analysis of Northern Hemisphere 50 kPa geopotential heights from 1946 to 1985. J. Climate, 3, 543-557.

van Loon, H., and J. Wiliams, 1976: The connection between trends of mean temperature and circulation at the surface. Part I: Winter. Mon. Wea. Rev., 104, 365-380.

van Loon, and J. C. Rogers, 1978: The seasaw in winter temperatures between Greenland and north Europe. Part I: General description. Mon. Wea. Rev., 106, 296-310.

Wallace, J. M., and D. S., Gutzler, 1981: Teleconnections in geopotential height field during the Northern Hemisphere winter. . Mon. Wea. Rev., 109, 784-812.