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Human climates of Egypt

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Abstract:

The clo index values for different wear have been estimated for daytime and nighttime for different months of the year in order to investigate human climates in Egypt. The clo values may also be used as a good guide to gauge the thermal human comfort under different atmospheric conditions and also express the resistance to heat transfer by clothing, and are expressed relative to the units of thermal insulation. A complete set of measurements for air temperature and cloud amount in addition to wind speed for the daytime (1200 GMT) and nighttime (0000 GMT) hours for the period 1991–2002 at 40 meteorological stations in Egypt have been used. The percentage area (%) requiring different weather wear during daytime and nighttime for all the months of the year have been determined. The study revealed that the whole country is characterized by the requirement of very cold weather wear during winter nighttime while 72% of the area of the country requires tropical weather wear during summer daytime. Only 71% of the area of the country requires comfortable weather wear during summer nighttime while there is no area requiring comfortable weather wear during winter nighttime. Latitudinal gradient of clo values was observed during all months of the year. Maximum latitudinal gradients of clo values during the daytime were found for the months of April and May. The clo classification in relation to climate has been done for Egypt. Copyright © 2006 Royal Meteorological Society

KEY WORDS human climates; clo index; weather clothing ensemble; thermal insulation; urbanization; Egypt

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INTRODUCTION

The thermal sensation of a human being is mainly related to the energy balance in the body as a whole. This balance is influenced by two groups of factors, personal and physical. The activity level and thermal insulation of the clothing used by the subject form the group of personal factors, while the environmental parameters (air temperature, air velocity, and air humidity) compose the group of physical factors. Furthermore, the surface temperature of the body is affected by the amount of heat transferred from the core of the body, by the heat losses from the body, and also by the insulation value of the clothing. The thermal resistance of clothing is given by the clo value. The clo index is expressed in terms of the clo unit (clo). The clo index combines both the atmospheric variables and activity levels, and conveys the actual amount of clothing required to maintain comfort. The approximate clo for some common clothing ensembles is shown in Table I.

A number of indices utilizing some of the human comfort factors based on the physiological feeling of a large number of people have been proposed by different authors (Venkiteshwaran and Swaminathan (1967), Lakshmanan (1984), Höppe (1999) and Matzarakis *et al.* (1999)). An excellent review of comfort models and thermal adaptation appears in many studies (Gagge *et al.* (1986), Tham and Ullah (1993), Brager and de Dear (1998), Robaa (1999), Peter *et al.* (2000), Kien (2001), Robaa (2003a) and Spagnolo and de Dear (2003)).

Egypt has a subtropical climate. It is located in an arid to semi-arid zone. The population of Egypt is about 70 million (Robaa and Hafez, 2002). The inhabited area of the country constitutes only 4% of the total area of the country (one million km^2), and the rest of the area is desert. The coastal zone of Egypt extends for more than 3500 km and is home to more than 40% of the population. Most of these people live in and around a number of very important and highly populated industrial and commercial cities: Alexandria, Port Said, Damietta, Rosetta and Suez. The climate of Egypt in the winter season (December–February) is cold, moist and rainy while in the summer season (June–August) the climate is hot, dry and rainless, and clear skies, prevail. The main features in the spring season (March–May) are the desert- or Khamsin depressions. They are always associated with strong, hot and dry winds that are often laden with dust and sand, increasing the atmospheric pollution. The climate in autumn season (September–November) is similar to that in spring as it is another transitional season. Khamsin-like depressions begin to cross Egypt during late September and cause a breakdown of the settled summer regime. On the other hand, the higher humidity in

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Table I. Approximate insulating values (clo) for common clothing ensembles.

Clothing ensemble	Clo
Shorts	0.1
Tropical wear: shorts, open-neck cotton shirt with short sleeves, sandals	0.3–0.4
Light summer wear: long light-weight trousers, open-neck shirt with short sleeves, shoes and socks	0.5–0.6
Light outdoor sportswear: T-shirt, cotton shirt, trousers, single ply cotton and dacron jacket	0.7–0.9
Typical business suit with associated shirt and undergarments	1.0
Typical business suit plus cotton coat	1.5
Heavy traditional European business suit: long cotton underwear, shirt, woolen socks, trousers, jacket and vest	1.5
Business suit plus substantial overcoat and woolen hat	1.8–2.5
All woolen winter sportswear: shirt, gloves, long underwear, socks, heavy coat and hat	2.6–3.5
Polar weather ensemble: long woolen underwear, coveralls, wind resistant parka with hood, mittens and fur-lined boots	3.6–4.7

(Cited from: De Freitas, 1979; Yan, 2005).

this season favors greater frequency of thunderstorms and heavier precipitation, a fact especially true in November.

The aims of this study are to examine the temporal and spatial variations of human thermal climate by using the clo index. The results of this study are useful for native people and as a guide to tourists or visitors for understanding human thermal comfort, planning outdoor recreational activities and developing the tourist industry.

METHODOLOGY AND ESTIMATIONS

The clo

The clo unit was introduced by Gagge *et al*. (1941) to express the relative resistance to heat transfer by clothing. A clo is a unit of thermal insulation that will maintain comfort in a resting/sitting person whose metabolic rate is 58 W m^{-2} (50 kcal m^{-2} h^{-1}), at an environmental temperature of 21 °C, air movement of 10 cm s^{-1} and relative humidity less than 50%. One clo can be defined as the amount of insulation that allows the transfer of 1 W m^{-2} with a temperature gradient of 0.155 °C between two surfaces (0.18 °C kcal^{-1} m^{-2} h^{-1}) (Gagge *et al*., 1941).

This concept is now used because it standardizes the discussion on thermal insulation of clothing. The ideal amount of clothing, in clo, necessary for comfort for different metabolic activities and various outdoor conditions can be predicted and computed. The approximate clo for some common clothing ensembles of the native people and tourists is shown in Table I.

Calculation of clothing requirements (in clo)

De Freitas (1979) and recently Yan (2005) showed that the thermal environment in terms of clothing requirements for comfort is

$$I_{cl} = \frac{33 - T_a}{0.155H} - \frac{H + R}{(0.62 + 1.9V^{0.5})H}\text{clo} \quad (1)$$

The solar heat load on a human (R) can be calculated by

$$R = R_o \cos\alpha p^m (1 - C^x) a_r b \quad (2)$$

where R_o is the solar constant, which is taken to be 1370 Wm^{-2}, α is the solar angle, p is atmospheric transmissivity, m is optical air mass, T_a is dry air temperature (in °C), H is the rate of dry heat transfer to the environment, V is wind speed (in m s^{-1}), C is cloud cover (in tenths), x is cloud transmission, a_r is the body surface area receiving radiation, and b is the absorptivity of the body surface (Auliciems *et al*., 1973; Yan, 2005). Solar angle (α) can be calculated by

$$\sin\alpha = \sin\phi\sin\delta + \cos\phi\cos\delta\cosh \quad (3)$$

where ϕ is the latitude of the location, δ is the solar declination, and h is the hour angle (List, 1963).

The clo, as a measure of insulation, refers to a positive state of thermal resistance. Negative clo values are set at zero (De Freitas, 1979). It is perceived that a clo value of zero implies a naked body, and a negative value indicates positive heat load, i.e. extreme discomfort.

To compute hourly clo values, some assumptions have to be made. In order to provide the necessary clothing protection, 116 W m^{-2} was chosen as the amount of metabolic rate for the lower limit of the light class of work (Auliciems and de Freitas, 1976; De Freitas, 1979). This value of metabolism is also equivalent to walking outdoors at a speed of about 2.0 m s^{-1}. The mean value of atmospheric transmissivity, p, in the middle latitude was found to be 0.9 and 0.87 for cold and warm seasons, respectively (De Freitas, 1979). In Egypt, p values have been found to be 0.88 and 0.83 for cold and warm seasons, respectively (El-Hussainy, 1986).

The term x, for cloud transmission, is related to optical air mass. Using a mean optical air mass value, x was estimated to be 0.47 in cold season and 0.43 in warm season. An average value of 0.45 was used in this study. Correction for average cloud cover is required (Hay, 1970), and the corrected exponent used in this study was $C^{1.45}$.

The total radiation absorbed by the body varies according to the body surface receiving the radiation (a_r and the absorptivity of body surface, b). It is assumed that a_r is 40% in cold season and 20% in warm season. Because diffused radiation and reflected radiation are of equal importance to direct radiation, and as these indirect sources can double the present a_r values (Auliciems and de Freitas, 1976; Auliciems and Kalma, 1979), it was

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decided that $a_r b$ values for cold season and warm season were 40–80% and 20–40%, respectively. The absorptivities of clothing are 90% for black, 60% for khaki and 20% for white (Auliciems *et al.*, 1973). The combined total absorptivity factors ($a_r b$) were 0.6 for cold season (De Freitas, 1979) and 0.2 for warm season, because light colored clothing is worn (Yan and Oliver, 1996).

Yan and Oliver (1996) and Yan (2005) used the above assumptions and the appropriate values according to Equations (1) and (2) to obtain the final Equations (4) and (5) for the computation of cold season (December–May) and warm season (June–November) clo values, respectively, as follows:

$$I_{cl} = \frac{33 - T_a}{13.485} - \frac{87 + 822\cos\alpha 0.9^m(1 - C^{1.45})}{87(0.62 + 0.19V^{0.5})}\text{clo} \quad (4)$$

$$I_{cl} = \frac{33 - T_a}{13.485} - \frac{87 + 274\cos\alpha 0.87^m(1 - C^{1.45})}{87(0.62 + 0.19V^{0.5})}\text{clo} \quad (5)$$

Yan and Oliver (1996) and Yan (2005) suggested also the limits of clo values as a climate clothing index, as given in Table II. They derived the combination of clothing for each group from the individual values for identified clothing given in Table I. The Equations (4) and (5) of Yan and Oliver (1996) and the limits of clo values that are given in Table II have been used in the present study to compute the monthly mean daily values of clo and in turn the description of the clothing required during daytime and nighttime throughout the yearin Egypt.

Table II. The limits of clo values and its corresponding clothing description (Yan and Oliver, 1996 and Yan, 2005).

Clo value	Clothing description
>2.5	Very cold wear
1.75–2.5	Cold wear
1.0–1.74	Comfortable wear
0.25–0.99	Summer wear
<0.25	Tropical wear

Data used

The monthly mean daily values, at 0000 GMT and 1200 GMT (Local apparent time, LAT = GMT − 2 hour), of measured dry air temperature, T_a (°C), wind speed, V (m s^{-1}), and cloud amount (in tenths) for the period 1991–2002 at 40 selected stations have been taken from the Egyptian Meteorological Authority and used in this study. The corresponding values of α and m have been calculated and also used in this study. The stations have been chosen to cover the whole of Egypt. The selected stations and their geographical coordinates are given in Table III and Figure 1. The time of observations at 0000 GMT and 1200 GMT have been also used to represent the nighttime and daytime hours, respectively. The values of clo have been calculated for different months and the results are illustrated by charts. These charts have been analyzed according to the limits of clo given in Table II, and the required clothing description during daytime and nighttime throughout the year have been identified for all the zones of Egypt. The area of Egypt has been divided into grids in order to determine the percentage area (%) requiring different weather wear during daytime and nighttime for all months of the year throughout the country. The results are given in Table IV.

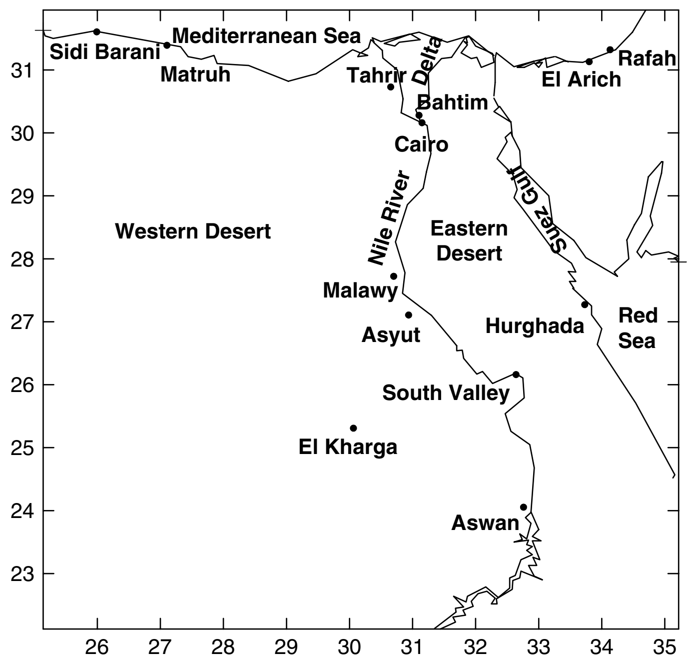

Figure 1. Map of Egypt.

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Table III. Station names and their numbers (World Meteorological Organization, WMO) and coordinates.

Station No.	Station	Lat. N	Long. E	Sta. No	Station	Lat. N	Long. E
062 301	Sidi Barrani	31°37′	25°54′	062 392	Asyut	27°12′	31°10′
062 305	Salloum	31°34′	25 18′	062 397	Sohag	26°34′	31°42′
062 306	Matruh	31°20′	27°13′	062 405	Luxor	25°40′	32°42′
062 307	Habatah	31°06′	25°57′	062 408	Edfou	24°59′	32°49′
062 309	Dabaa	30°56′	28°28′	062 414	Aswan	23°58′	32°47′
062 318	Alexandria	31°11′	28°27′	062 417	Siwa	29°12′	25°29′
062 325	Baltim	31°33′	31°06′	062 420	Baharia	28°20′	28°54′
062 330	Damieta	31°25′	31°49′	062 432	Dakhla	25°29′	29°00′
062 335	Rafah	31°13′	34°12′	062 435	Kharga	25°27′	30°32′
062 336	El-Arich	31°05′	33°50′	062 438	Abu Swair	30°34′	32°06′
062 339	Damanhour	31°02′	30°28′	062 440	Ismailia	30°36′	32°15′
062 345	Tahrir	30°39′	30°42′	062 450	Suez	29°52′	32°28′
062 349	Tanta	30°49′	30°56′	062 455	Ras-Sedr	29°36′	32°42′
062 351	El Khatatba	30°19′	30°52′	062 456	Ras-Elnakab	29°36′	34°47′
062 365	Belbaiss	30°24′	31°35′	062 461	Nuwaibaa	28°58′	34°41′
062 371	Cairo	30°05′	31°17′	062 463	Hurghada	27°09′	33°43′
062 377	Helwan	29°43′	31°12′	062 465	Kosseir	26°08′	34°18′
062 381	Fayoum	29°18′	30°51′	062 466	Safagah	26°45′	33°57′
062 387	Minya	28°05′	30°44′	062 475	Ras Benas	23°58′	35°30′
062 389	Mallawi	27°42′	30°45′	062 476	Shelateen	23°07′	35°34′

Table IV. The percentage area (%) requiring different weather wear during daytime (1200 GMT) and nighttime (0000 GMT) in different seasons and for all months of the year throughout Egypt.

Month		Very cold	Cold	Comfort	Summer	Tropical
Jan	Daytime	48	48	4	0	0
	Nighttime	100	0	0	0	0
Feb	Daytime	26	64	10	0	0
	Nighttime	100	0	0	0	0
Mar	Daytime	10	30	40	20	0
	Nighttime	95	5	0	0	0
Apr	Daytime	0	8	22	29	41
	Nighttime	30	60	10	0	0
May	Daytime	0	6	18	31	45
	Nighttime	6	64	30	0	0
Jun	Daytime	0	0	8	26	66
	Nighttime	0	47	53	0	0
Jul	Daytime	0	0	3	17	80
	Nighttime	0	7	70	23	0
Aug	Daytime	0	0	5	26	69
	Nighttime	0	5	91	4	0
Sep	Daytime	0	0	11	25	64
	Nighttime	0	28	70	2	0
Oct	Daytime	0	4	24	41	31
	Nighttime	3	92	5	0	0
Nov	Daytime	0	11	42	43	4
	Nighttime	80	20	0	0	0
Dec	Daytime	13	29	45	9	4
	Nighttime	100	0	0	0	0
Winter	Daytime	29	47	20	3	1
	Nighttime	100	0	0	0	0
Spring	Daytime	3	15	27	27	29
	Nighttime	44	43	13	0	0
Summer	Daytime	0	0	5	23	72
	Nighttime	0	20	71	9	0
Autumn	Daytime	0	5	26	36	33
	Nighttime	28	47	25	1	0

RESULTS AND DISCUSSION

It can be noticed that there is a latitudinal gradient for clo values, which decrease from north to south. This is due to the north to south increase of air temperature and decrease of cloud cover. On the other hand, it was found that this latitudinal gradient is strong during daytime (1200 GMT) compared to nighttime (0000 GMT) (Figures 2, 3, 4 and 5). Furthermore, the daytime in April and May months have the maximum latitudinal gradient among all months of the year. This may be attributed to the Khamsin depressions that are more common over Egypt during the spring season (March–May). These depressions are characterized by southerly hot and dry winds that distinctly cause a decrease in the amount of cloud cover and an increase in the air temperature and wind speed, especially over the region of Upper Egypt (Robaa, 2003b). This in turn leads to a decrease in the clo values over Upper Egypt and an increase in the latitudinal gradient, especially during daytime when the Khamsin effect combines with the higher actual solar heating.

Winter season (December to February)

Daytime hours. During December (Figure 3(f)), the average clo values ranged from below 0.25 at the extreme

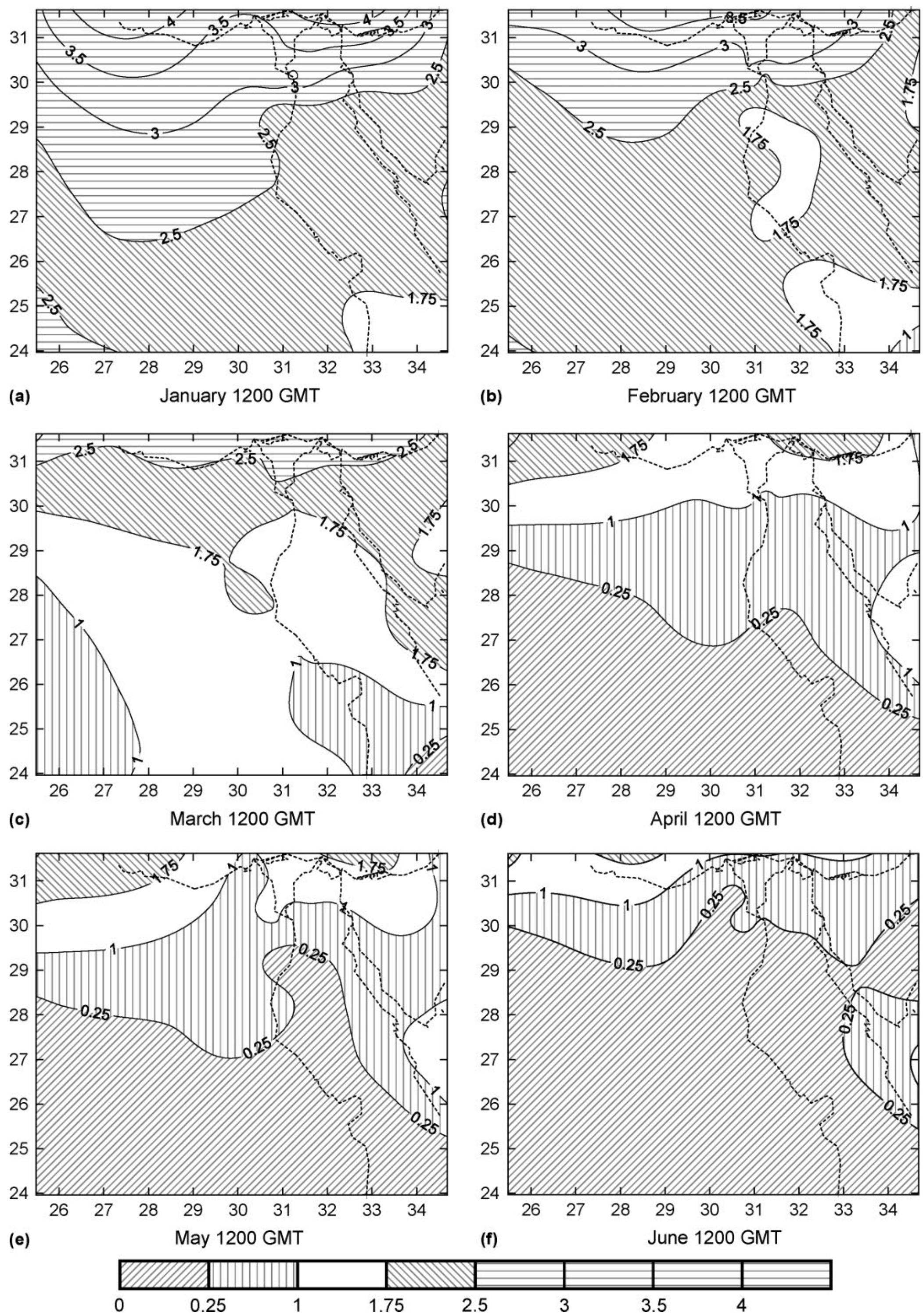

Figure 2. Clo index values for Egypt during the daytime (1200 GMT) for the months (a) January, (b) February, (c) March, (d) April, (e) May and (f) June.

southwest of the country to greater than 2.5 along the Mediterranean coast in the north. Comfortable weather wear (1 < clo < 1.75) are required in 45% of the country that lie completely in the southern half. Summer (0.25 < clo < 1) and tropical (clo <0.25) weather wear are required, respectively, in 9% and 4% areas of the country located at the southwest boundary. Cold, (1.75 < clo < 2.5) and very cold, (clo >2.5) weather wear are required at the upper third of the country and this area extends to the north to represent 42% of the country's area (Table IV).

In January (Figure 2(a)), cold and very cold weather wear (clo >2.5) are required in 96% area of the country. A spot representing the remaining 4% area and requiring comfortable weather wear (1 < clo < 1.75) has been found at the extreme southeast of the country (Table IV).

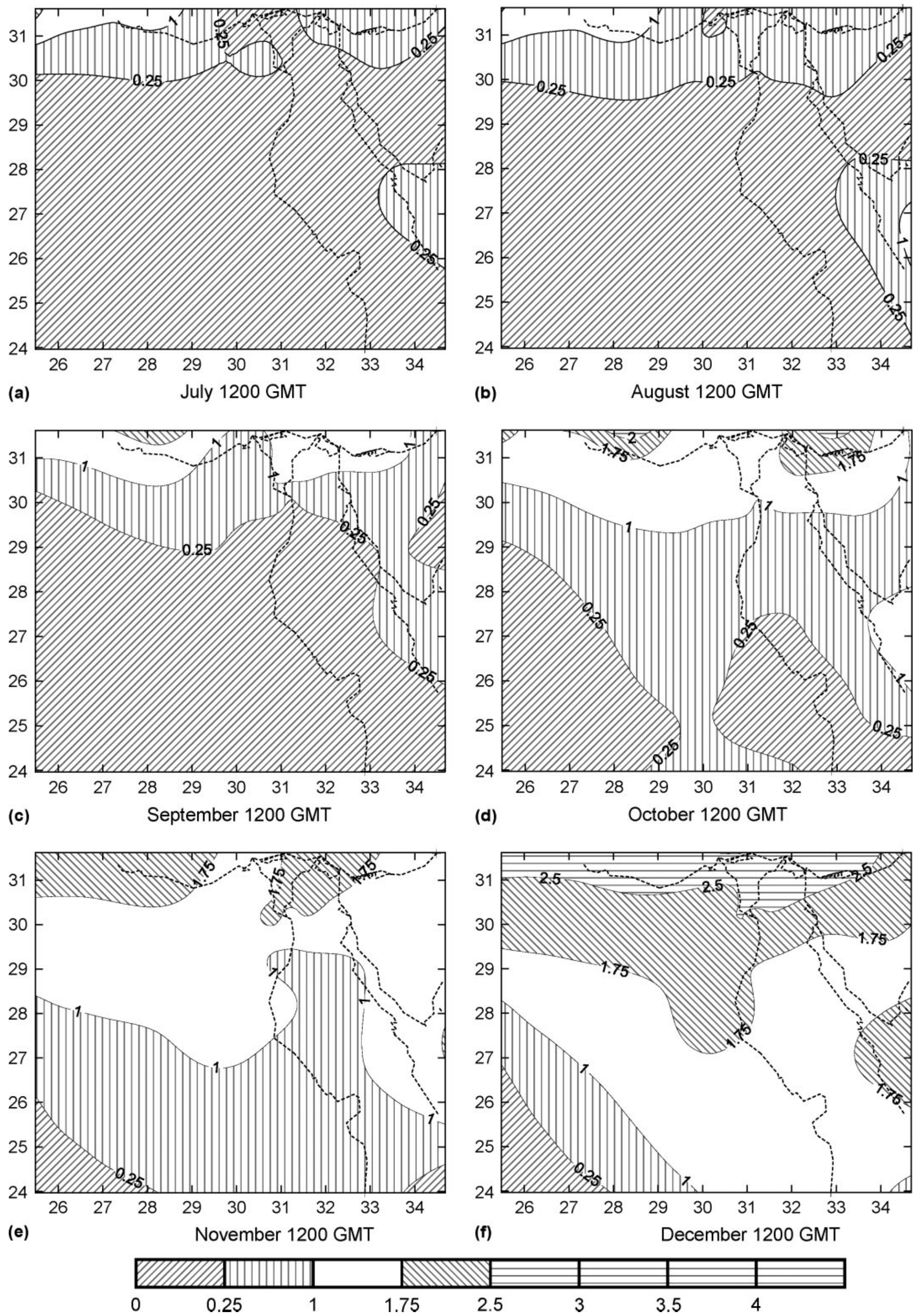

Figure 3. Clo index values for Egypt during the daytime (1200 GMT) for the months (a) July, (b) August, (c) September, (d) October, (e) November and (f) December.

The pattern in February is similar to that of January (Figure 2(a) and (b)); however, the spot of area in the southeast, requiring comfortable weather wear, relatively increases and there is an additional appearance of another strip in the eastern desert. The total area of the country requiring comfortable weather wear was found to be 10% instead of the 4% found during January (Table IV).

Nighttime hours. Figure 4(a) and (b) and Figure 5(f) show that the whole country has clo values greater than 3 during nighttime hours in winter months. It implies that very cold weather wear are always required during this time. This is attributed to the northerly cold air that invades Egypt during these months in addition to the reduction of air temperatures due to radiation during the night hours in the course of diurnal variation.

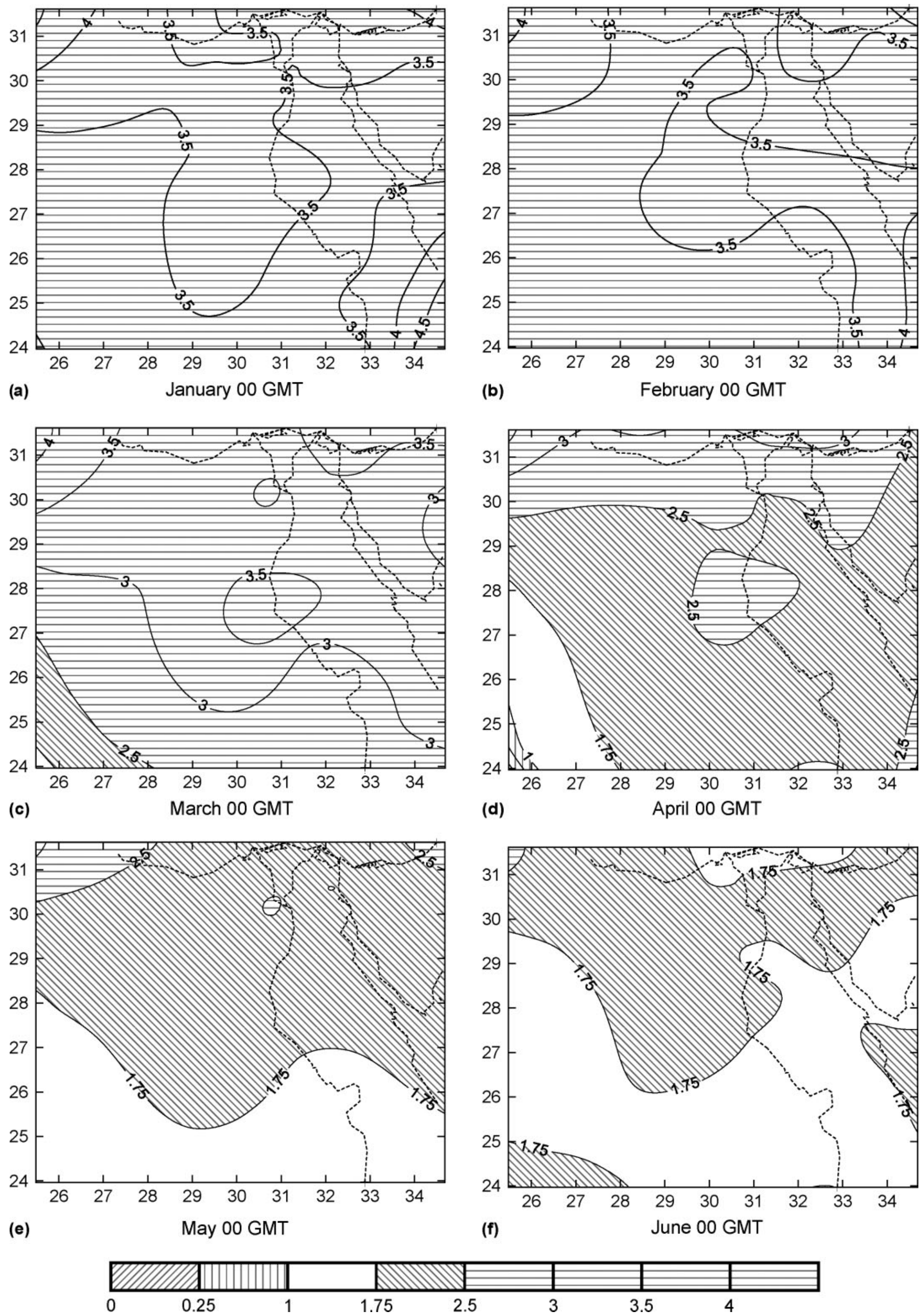

Figure 4. Clo index values for Egypt during the nighttime (00 GMT) for the months (a) January, (b) February, (c) March, (d) April, (e) May and (f) June.

Spring season (March to May)

Daytime hours. During March (Figure 2(c)), comfortable weather wear (1 < clo > 1.75) are required in the 40% area that lies in two spots in the southern two-thirds of the country. These two big spots, representing 20% each of the country and requiring summer weather wear (0.25 < clo < 1), have been found at the extreme southeast and southwest of the country. The northern third of the country is divided into two categories for the requirement of weather wear. The first part is the Mediterranean coast consisting of 10% of the country and requiring very cold weather wear (clo >2.5) while cold weather wear (1.75 < clo < 2.5) are required in the second part representing 30% of the country and extending to the southeast over the Red sea (Table IV).

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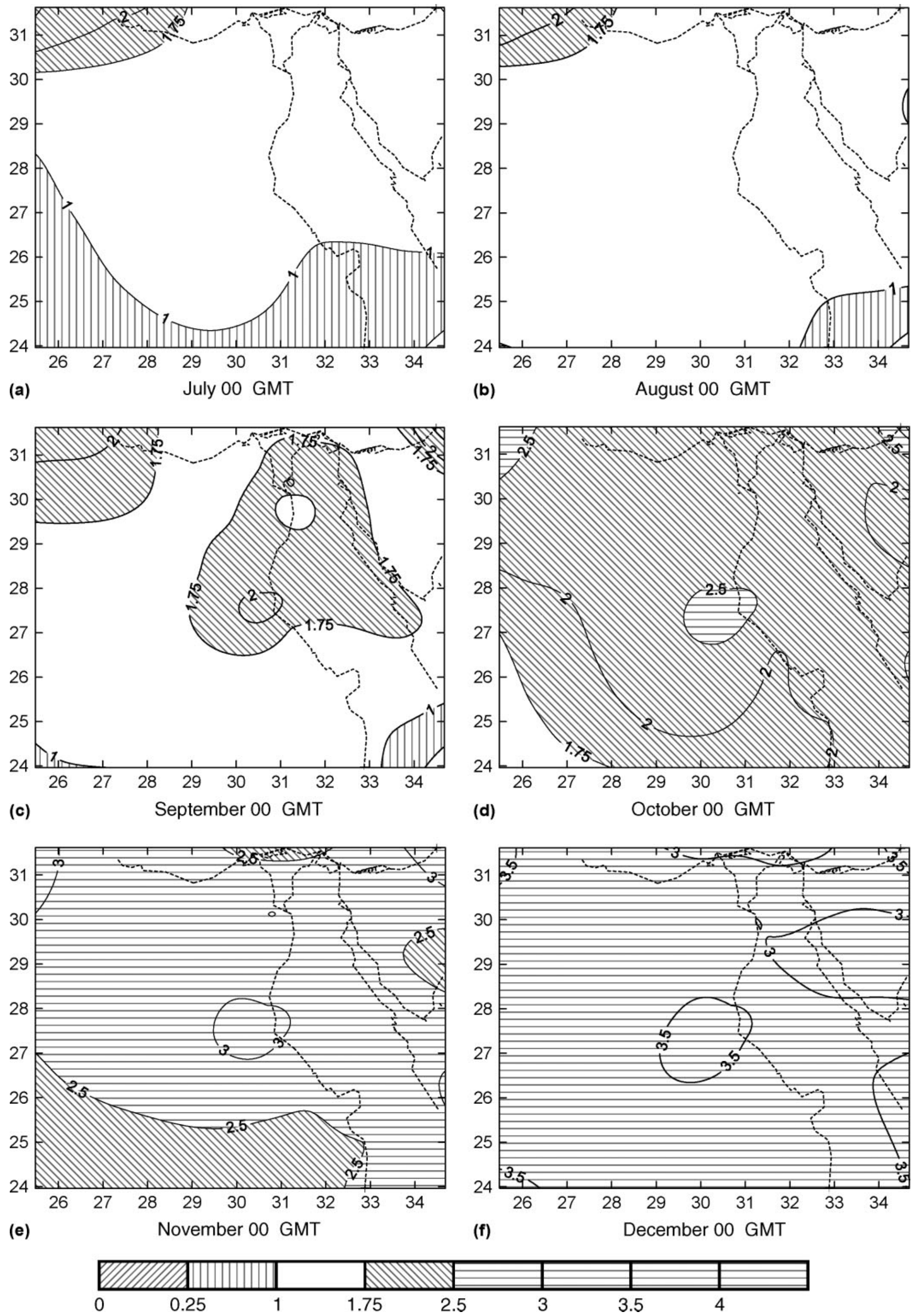

Figure 5. Clo index values for Egypt during the nighttime (00 GMT) for the months (a) July, (b) August, (c) September, (d) October, (e) November and (f) December.

In April (Figure 2(d)), the country is divided into three categories according to requirement of the type of weather wear. The type of weather wear graduates from the lighter wear in the south of the country to very heavy wear in the extreme north. Comfortable weather wear ($1 < \text{clo} < 1.75$) are required in 22% area that lie in the northern third of the country, in addition to a big spot in the extreme east over the Red sea. Small spots requiring cold weather wear ($1.75 < \text{clo} < 2.5$) and representing 8% area have been found at the extreme northeast and northwest of the country. Summer weather wear ($0.25 < \text{clo} < 1$) are required in 29% area that lie in the middle third of the country, while tropical weather wear ($\text{clo} < 0.25$) are required in 41% that lie in the southern third (Table IV).

The pattern in May is similar to that of April (Figure 2(d) and (e)); however, the zone requiring comfortable weather wear decreases to 18% of the

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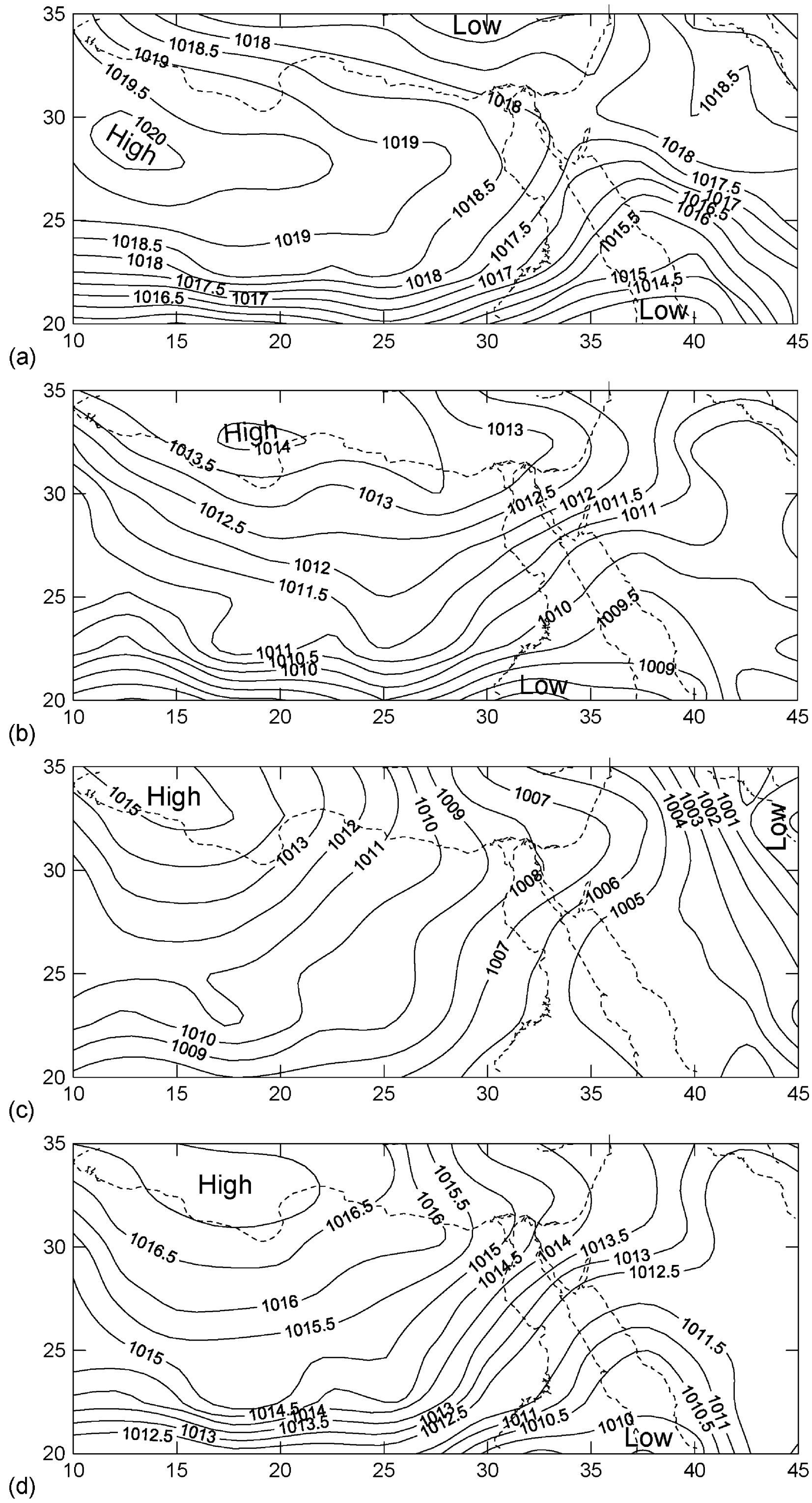

Figure 6. Seasonal mean sea-level pressure for the period 1961–1990 over Egypt during (a) winter, (b) spring, (c) summer and (d) autumn.

country's area. Furthermore, the areas requiring summer and tropical weather wear increase and extend to the north to cover 79% of the area (Table IV).

Nighttime hours. During March, the whole country has clo values greater than 2.5, except for a spot lying at the extreme southwest and representing 5% area of the country, and requires cold weather wear (1.75 < clo < 2.5). This implies that very cold weather wear are always required in 95% of the country during nighttime in March. This is attributed to the reduction of air temperatures due to radiation during the night hours in the course of diurnal variation (Figure 4(c) and Table IV).

Cold weather wear (0.25 < clo < 1) are required in April in 60% of the country. However, very cold weather wear (clo >2.5) are required in 30% of the country consisting of different localities in the northern third, a circular area in the middle country and a very small strip in the extreme southeast. On the other hand, comfortable weather wear ($1 < clo < 1.75$) are required for the remaining 10% of the country comprising a large strip in the extreme southeast (Figure 4(d) and Table IV).

In May (Figure 4(e) and Table IV), comfortable weather wear are required for 30% area located at the southern third of the country while cold weather wear ($1.75 < clo < 2.5$) are required for most of the remaining part that represents 64% of the area. Two small spots requiring very cold weather wear and representing 6% area of the country have been found in the extreme northeast and northwest boundaries.

Summer season (June to August)

Daytime hours. The pattern in June is similar to that in May (Figure 2(e) and (f)); however, the requirement of comfortable ($1 < clo < 1.75$) and summer weather wear ($0.25 < clo < 1$) distinctly decreases to cover, respectively, 8% and 26% of the country's area. On the other hand, the requirement of tropical weather wear ($clo < 0.25$) increases and extends to the north and covers 66% of the country's area, (Table IV).

The pattern of July is much similar to that of June (Figure 2(f) and Figure 3(a)); however, the zones requiring comfortable and summer weather wear deceases to 3% and 17% of the country's area, respectively, and consist of only the tourist area of Hurghada and the Mediterranean coast (Table IV). On the other hand, the requirement of tropical weather wear increases to cover most of the country.

The pattern of August is very similar to that of July (Figure 3(a) and (b)); however, the zones requiring comfortable and summer weather wear somewhat increase to cover 5% and 26% of the country's area, respectively, while the zone requiring tropical weather wear show the opposite behavior and decreases to 69% area of the country instead of the 80% for July (Table IV).

Nighttime hours. During June (Figure 4(f)), cold weather wear ($1.75 < clo < 2.5$) are required in 47% area of the country. Most of this area is situated in the country's northern half and, in addition, there are two small spots at the tourist area of Hurghada and the extreme southwest of the country (Table IV). On the other hand, there is a requirement of comfortable weather wear in the remaining 53% area of the country, and most of this area is situated in the country's southern half, in addition to the different localities that comprises most of Sinai, the Suez Gulf, a part of the Nile valley, the region between these areas and a small spot at the eastern coast of the Mediterranean.

Comfortable weather wear ($1 < clo < 1.75$) are required for 70% of the country during nighttime in July. The country's 23% area located in the southern third requires summer weather wear ($0.25 < clo < 1$), while cold weather wear ($1.75 < clo < 2.5$) are required for only 7% of the country covering the extreme northwest (Figure 5(a) and Table IV).

The whole country is characterized by the requirement of comfortable weather wear ($1 < clo < 1.75$) during nighttime in August (Figure 5(b)), except for two small spots. The first spot, representing 5% of the country's area and lying at the extreme northwest, is characterized by the requirement of cold weather wear ($1.75 < clo < 2.5$), while the second spot, representing 4% of the country's area and lying at extreme southeast, is characterized by the requirement of summer weather wear ($0.25 < clo < 1$) (Table IV).

Autumn season (September to November)

Daytime hours. The pattern in September is much similar to that in August (Figure 3(b) and (c)); however, the areas requiring comfortable weather wear ($1 < clo < 1.75$) fairly increase to cover 11% of the country while the zones requiring summer ($0.25 < clo < 1$) and tropical ($clo < 0.25$) weather wear somewhat decrease to 25% and 64% of the country's area, respectively (Table IV).

In October (Figure 3(d)), the zones requiring comfortable and summer weather wear increase and extend to the south, covering 24% and 41% of the country, respectively. The zone requiring tropical weather wear shows the opposite behavior and reduces to two big zones representing only 31% of the country's area. One of these zones lies at the southwest boundary of the country as a big strip in the western desert and the other zone comprises the southern part of the Nile valley with the eastern and western deserts that surround it.

The pattern in November is similar to that in October (Figure 3(d) and (e)); however, the areas requiring comfortable and cold weather wear distinctly increase to cover 42% and 11% of the country's area, respectively. On the other hand, the zone requiring summer weather wear fairly increases and extends to the south and covers 43% of the country's area. It replaces the zones requiring tropical weather wear, which reduce to become a small spot representing only 4% of the area and lying at the extreme southeast of the country (Table IV).

Nighttime hours. The pattern in September is much similar to that in August (Figure 5(b) and (c)); however, the area requiring cold weather wear ($1.75 < clo < 2.5$) distinctly increases to cover 28% of the country instead of the 5% during August (Table IV). The area requiring cold weather wear is represented by a big triangular area that includes a part of the Nile Delta, the Suez Gulf, a part from the Nile valley, the region between them, a big part of the western desert along the Nile valley in addition to the area that lies at the extreme northwest boundary. Furthermore, the urban area of Cairo is characterized by the requirement of comfortable weather wear, which may be due to a relative increase in air temperature and decrease in wind speed induced by urbanization processes (Robaa, 1999).

In October (Figure 5(d)), cold weather wear are required for the whole country, except for very small spots that represent 3% of the country's area and is characterized by the requirement of very cold weather wear (clo >2.5). The zone requiring comfortable weather wear (1 < clo < 1.75) distinctly reduces to a small strip in the southwest corner of the country inside the western desert, and represents 5% of the country's area (Table IV).

Very cold weather wear (clo >2.5) are required for 80% of the country's area during nighttime in November (Figure 5(e)). On the other hand, the region requiring cold weather wear (1.75 < clo < 2.5) distinctly reduces to cover the remaining 20% area instead of the 92% during October (Table IV). There is a requirement in 20% of the area for cold weather wear and it comprises the southeast of Sinai and the extreme north Delta on the Mediterranean coast in addition to a big horizontal strip at the extreme south of the country in the western desert.

Clo classification over Egypt

During days and nights in winter, cold and very cold weather wear prevail and are required for most parts of the country, especially along the Mediterranean coast and Lower Egypt, while Upper Egypt is characterized by a requirement of comfortable weather wear. This is due to the fact that Egypt is affected by two pressure situations in winter, the Cyprus low and the traveling depressions over the Mediterranean. These depressions mainly affect Lower Egypt and cause extreme bad weather while upper Egypt remains practically untouched. The formation of a quasi stationary low in the domain of Cyprus Island in winter is quite common (Figure 6(a)), and this represents the main mechanism underlying the development of deep depressions in the eastern Mediterranean. When the Cyprus low is already situated in its position in north Egypt, successive cold fronts are remarkable on the weather charts and the surface winds become fresh and south to southwest over Egypt. After that, the wind veers gradually to northwest and the weather becomes cooler, the coldest spells are then experienced, humidity increases and much of the low clouds are formed. Showers develop frequently and may continue for several days until the low moves away. Thunderstorms may also occur and coastal gales are frequent. The cold northwesterly winds in the rear of the depressions continue their journey southwards to upper Egypt and cause a reduction in the temperature. On the other hand, the north coast of Africa and the Middle East are affected to a greater extent by the moving depressions over Europe, especially when these lows are associated with a deep cold trough. In front of these depressions the surface winds are south to southwesterly. These lows cause rain, showers and sometimes thunderstorms along the African coast. However, in some cases, when the low reaches Egypt, the polar air associated with it is modified and becomes dry. When the low is in east Mediterranean, the orography around east Mediterranean, the warm water of the sea, and the warm air flow from the south reinforce the depression and the instability arises again. When the low moves far away from east Mediterranean, a cell of high pressure is formed in the area (Figure 6(a)), and then the NE winds will prevail and early morning radiation fog may be formed (Griffiths and Soliman (1972), El-Asrag (1983) and Hasanean (1992)).

In spring season, most of the types of weather wear are required in the country during daytime and nighttime, whereas it is characterized by alternative requirements between tropical weather wear during daytime and very cold weather wear during nighttime. Furthermore, the wear types graduate from lighter wear in the south of the country to very heavy wear in the extreme north. This is due to the fact that spring season is a transitional season and it has some of the features of both winter and summer. The entire pressure system begins to move northward in spring (Figure 6(b)) and the land and sea-surface temperatures become warmer; however, the difference between their temperatures also becomes large. Showers and thunderstorms are experienced in this season, especially when the traveling depression over the Mediterranean invades the area. The centers of the depressions move either along the coast line of north Africa or further south, where they are known as desert or Khamsin depression. Some of these depressions are formed near the eastern part of Egypt when the Sudan Monsoon low arm is shifted up to the north coast of Africa. The average frequency of these depressions may vary between two and six per month. These depressions are smaller in area than the winter Mediterranean depressions and may be associated with more high and medium clouds, but much less rain. When the Khamsin low approaches Egypt, the high pressure over southwest Asia causes the hot easterly and northeasterly winds to blow over Egypt. When the Khamsin depression is already over Egypt, the wind veers to the south and then to the southwest. These lows cause dust storms, sandstorms and heat waves especially over south Egypt and a great difference in air temperature is then established between Lower and Upper Egypt. The air mass that is dominant in this period is the tropical continental air mass from the eastern or southern regions. All the large maximum temperature records are caused by this tropical continental air, which is, at the same time, also the reason for the low relative humidity records. After the Khamsin low passes an area, the temperature drops and the modified polar continental air invades the area (El-Asrag, 1983).

During daytime in summer, tropical weather wear prevail and are required for most parts of the country, while comfortable weather wear are required during nighttime. This is due to the fact that the general climate in summer is sunny, hot, dry and rainless. The maximum temperatures attain their peak in August. Clear skies often prevail, except for some coastal fair weather cumulus or early morning stratus clouds over Lower Egypt, which disperse a few hours after sunrise. In this season, depressions cease to move across Egypt and the weather becomes settled (Figure 6(c)). The climate of Lower and Middle Egypt, because of the affect of the cool Mediterranean water, is warm during the day and

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rather cool by night. The maximum effects are obviously in the coastal areas where the weather remains pleasant. The tropical continental hot air of west Syria and Iraq invades Egypt resulting in very high temperatures in the lower layers, making it most oppressive. Such heat waves are warmer and more oppressive than those of spring because, although the temperature may not be so high, there is high humidity (El-Asrag, 1983 and Hasanean, 1992).

Autumn season is also a transition season and its clo characteristics are similar to that in spring, but with a lower intensity. Autumn season is characterized by alternative requirements between summer weather wear during daytime and cold weather wear during nighttime. This is due to the fact that the general climate of autumn season is similar to that of spring. Khamsin-like depressions begin to cross Egypt during late September and cause a breakdown of the settled summer regime. The depressions at this time are much less vigorous than in spring and are slower in their eastward movement. In autumn, as in spring, the Sudan monsoon low becomes centered over the north of Sudan and its northward oscillation exerts direct influence on the weather (Figure 6(d)). As in spring, the northeast winds and early morning radiation fog are frequent. Heat waves are less common and less severe than in spring. This is because the depressions are weaker (El-Asrag, 1983 and Hasanean, 1992).

CONCLUSION

The following conclusions have been made from this research:

There is a latitudinal gradient for clo values during all the months of the year in Egypt. It is stronger during daytime compared to nighttime. The daytime of April and May have the maximum value of latitudinal gradient. This is due to the effects of Khamsin depressions that are more common during spring season over Egypt. The winter season is characterized by requirements of cold weather wear in 47% (mainly 64% in February) of the country's area during daytime, while during nighttime of this season the very cold weather wear prevail and it is required for 100% (mainly in December, January and February) of the country's area. The tropical weather wear are required for only 29% (mainly 45% in May) of the country during daytime in spring while the nighttime in this season is characterized by requirements of very cold weather wear in 44% (mainly 95% in March) of the country's area. The summer season is characterized by requirements of tropical weather wear in 72% (mainly 80% in July) of the country during daytime while the nighttime of this season is characterized by requirements of comfortable weather wear in 71% (mainly 91% in August) of the country's area. The summer weather wear are required for only 36% (mainly 43% in November) of the country during daytime in autumn while the nighttime of this season is characterized by requirements of cold weather wear at 47% (mainly 92% in October) of the country's area. The climatic impacts thus induce the clo classification during the four seasons in Egypt.

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