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HEAT WAVE OVER EGYPT DURING THE SUMMER OF 1998

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Abstract: During the summer of 1998, the Mediterranean area is subject to episodes of air temperature increase, which are usually referred to as "heat waves". These waves are characterised by a long lasting duration and pronounced intensity of the temperature anomaly. A diagnostic study is carried out to analyse and investigate the causes of this summer heat wave, NCEP/NCAR reanalysis data are used in this study. The increase of temperature during the summer of 1998 is shown to be due to the increase of the subsidence of: 1) the branch of the local tropical Northern Hemisphere Hadley cell; 2) the branch of the Walker type over the Mediterranean sea and North Africa; 3) the steady northerly winds between the Asiatic monsoon low and the Azores high pressure.

Keywords: Heat waves, Hadley cell, Walker type, Mediterranean Sea, Northern Hemisphere, Steady wind, monsoon, Azores high pressure, monsoon low,

INTRODUCTION

The earth's global temperature in 1998 was the hottest on record since 1860, according to the Intergovernmental Panel on Climate Change (IPCC, 2001). The global mean surface temperature was estimated to be 0.58 °C above the recent long-term average based on the period 1961-1990. It was the 20th consecutive year with an above normal global surface temperature. The ten warmest years have all occurred since 1983, with seven of them since 1990 (IPCC, 2001). The IPCC (2001) suggested that higher maximum temperatures and more hot days are likely to increase in frequency during the twenty first century. High in the atmosphere, where regular measurements are made by instruments on weather balloons and satellites, record temperatures also occurred. From the surface to 7 km altitude, record temperatures in 1998 were 0.47 °C higher than the average for the last 20 years, making 1998 by far the warmest year. In the lower stratosphere, 1998 was colder than usual, though not quite as cold as 1995-1997. Globally, preliminary surface data indicated that August 1998 (and the year from January-August) remained at record warm levels with respect to the 1880-1997 long-term mean. Preliminary, the August land station temperature was 1.2 °C above the mean, while sea surface temperature readings (including ship, buoy, and satellite measurements) were nearly 0.57 °C above the mean, for a combined index value of 0.72 °C above the average.

Summer air temperature is an issue of great concern, since their variability and extremes have important economical and social implications. Climate is the main factor that determines the tourism potential of a region (Matzarakis, 1999). Heat waves occurred during the summers of 1987 and 2000 with disastrous consequences for humans and forests, reduced the traditional peak summer demand at Mediterranean holiday destinations (IPCC Technical Summary 2001). In addition, heat waves have been associated with short term increases in mortality (Kovats *et al*., 1999) as well as with the exacerbation of the air pollution and the extension of vector borne diseases (IPCC Policy Makers, 2001).

High summer temperatures are harmful to human health. Analyses that examine heat-stress related mortality consider the apparent temperature, which attempts to quantify the joint effect of temperature and moisture on a human body (Steadman, 1984), or apply a synoptic approach proposed by Kalkstein (1991). For example, the very intense heat wave in July 1995 that affected the Midwestern U.S.A. caused over 800 deaths, most of them in Chicago (Whitman *et al*., 1997). The analysis of Karl and Knight (1997) indicated that for Chicago, such an extended period of continuously high daytime and night-time apparent temperatures is unprecedented in modern times. Changnon *et al*., (1996) presented a comparison of fatalities attributed to weather in the U.S.A. (e.g. tornadoes, floods, hurricanes, wind storms, etc.). The mean annual number of deaths caused by heat waves is much higher than that for any other extreme weather event.

Several climatological studies have focused on temporal and spatial fluctuations of extreme high-temperature events and increases in temperature thresholds. Prolonged extreme temperature events have been studied also (Kunkel *et al*., 1996, 1999; Domonoko, 1998; Karl and Easterling, 1999). Kunkel *et al*., (1999) found no evidence for changes in the frequency of intense heat waves since the 1930s in the U.S.A. The most frequent increase of threshold temperatures above which mortality rises significantly were observed in the 1930s, with 1936 recording the highest number. Kunkel *et al*. (1996) presented statistics of the most intense 4 day heat waves in Chicago between 1901 and 1995; the peak in the 1930-1940s was the dominant feature of their temporal distribution.

In this paper we investigate the causes of summer heat waves especially during August 1998. The meteorological extremes are described and discussed along with the east west variations in climatic parameters.

THE EXTREMES IN METEOROLOGICAL FACTORS

In this section we will show the climatological pattern of some meteorological variables (1960-2000) and its differences from 1998. Also, we will focus on the months July and August and try to illustrate why 1998 was warmer than the previous.

HEIGHT

Fig. 1a shows the horizontal distribution of the average for July (1960-2000) for mean sea level pressure and its difference from 1998 (Fig. 1b). It also shows the horizontal distribution of the average for July at 500 hPa (Fig. 1c) and their corresponding differences from 1998.

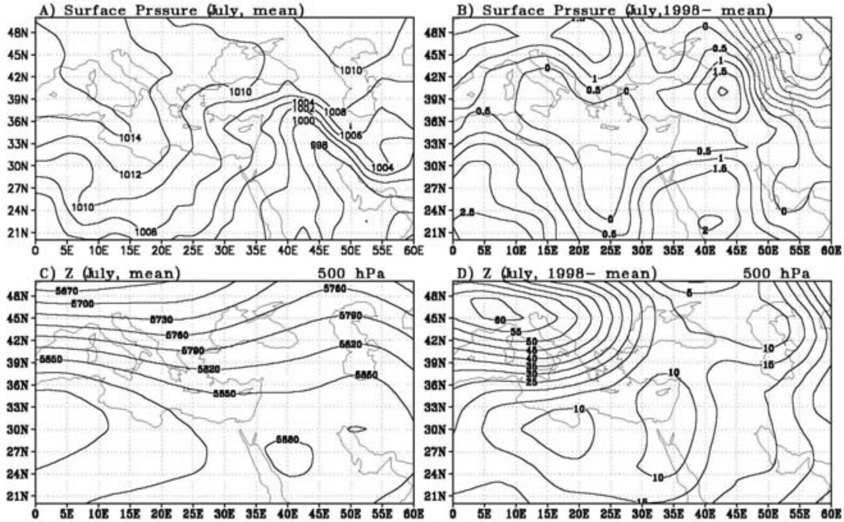

Fig. 1: a) The average mean sea level pressure (1960-2000) for July b) the difference of MSLP between July 1998 and the average July, c) the average values of geopotential height at 500 hPa level and d) the differences of geopotential height between July 1998 and the average July at 500 hPa.

Fig. 1a illustrates that the dominant pressure systems that affect the weather of this area during this time of the year are the subtropical high pressure which extended easterly to reach the east of the Mediterranean, and the Indian monsoon low which extended west to reach the east of Mediterranean. Fig. 1b shows that there is a small decrease of pressure over the Mediterranean and the west of Egypt while a pronounced increase of pressure occurs over east of Egypt, Red Sea and Saudi Arabia and also over Turkey. This situation dominates up to 850 hPa.

On the upper air (at 500 hPa) the subtropical high extended eastward (Fig. 1c) and its differences from 1998 (Fig. 1d) show that the increase of height over Egypt during 1998 is more than 10 m and it reaches up to 60 m over Europe. This increase of height in July 1998 than the average July (1960-2000) is more pronounced at 200 hPa (not shown) where it reaches more than 60 m over north of Egypt and more than 100 m over Europe. Fig. 2 is as Fig. 1 but for August. It illustrates that the mean sea level pressures at 1998 are more than average for August (1960-2000) except over the central Mediterranean, Lybia and west of Egypt. The difference of pressure exceeds 1 hPa over Lybia and south of Italy. This pattern occurs also at 850 hPa but the negative area decreased to become only over north Lypia, Algeria, Tunes and south of Italy (Fig. 2d). The positive values increases with height to reach greater than 100 m over Turkey at 200 hPa.

We can conclude from Figs. 1 and 2 that the subtropical height pressure system is weaker during 1998 and is seen to be mainly to the east of its climatological position. Due to this situation the extension of the Indian monsoon low oscillates to the west more than its average position.

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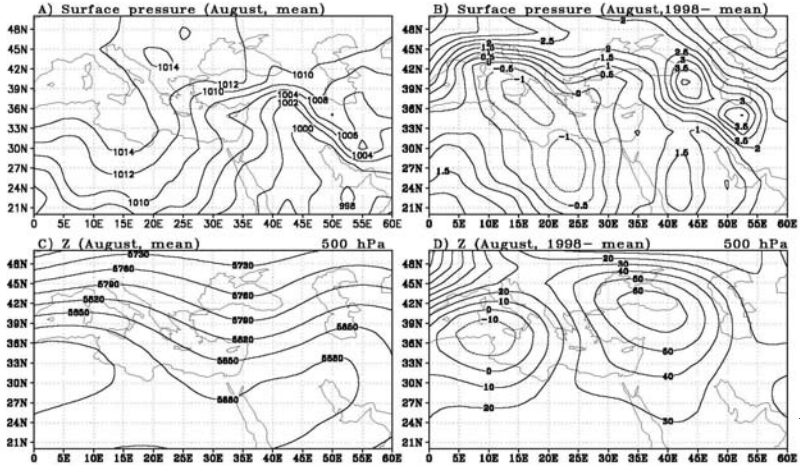

Fig. 2: as in Fig. 1 but for August.

TEMPERATURE

Fig. 3 illustrates the distribution of the average July (1960-2000) temperature and its differences from July 1998 at the mean sea level pressure and 500 hPa. Fig. 3a shows that the temperature increases from north to south and over the warmest area in our domain which is the Arabian Peninsula, and Iraq. The increase in temperature from north to south can be seen more obviously on 850 hPa (not shown), where the thermal trough extended from the north-west of our domain (northwest Italy) to reach Libya and south-west Egypt. The Arabian Peninsula is also the warmest area at 850 hPa, its temperature increases about 32o C. On 500 hPa this pattern of temperature distribution is changed and the warmer area extended westerly to the west of Lybia with the warmest one over Egypt (Fig. 3c).

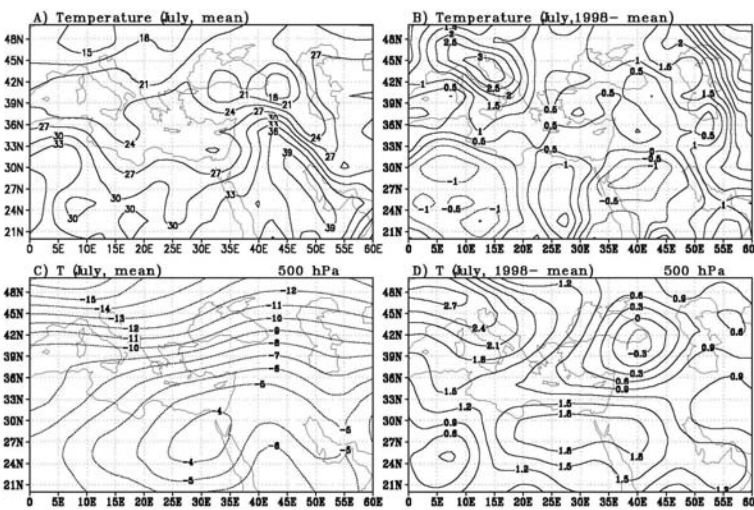

Fig. 3: a) The average surface temperature (1960-2000) for July, b) the difference of surface temperature between July 1998 and the average July, c) the average temperature at 500 hPa level and d) the difference of temperature between July 1998 and the average July at 500 hPa.

Fig. 3d shows that on 500 hPa the temperature of 1998 is higher than the average temperature over the most of our domain except only over north-east Mediterranean where small negative values occur. The maximum positive values appear over Egypt and extended from south Italy to northwest Europe. This rising temperature at 1998 occurs also over 200 hPa.

Fig. 4 illustrates the distribution of the temperature and the differences of the average values from the values of August 1998 at the mean sea level pressure and 500 hPa. It is interesting to note that the pattern of the distribution of the mean temperature during August at our interesting levels (Fig. 4a) is similar to the correspondence for July (Fig. 3a), but the values of temperature in July is more than that in August. Fig. 4b illustrate the differences between the temperature in 1998 and the average of 1960-2000.

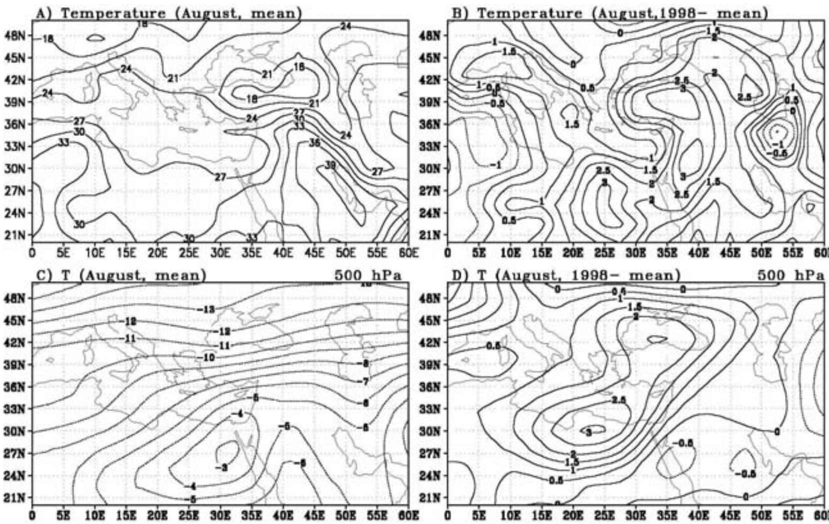

Fig. 4: as in Fig. 3 but for August.

It is clear that the 1998 is warmer than the mean throughout all levels and from longitude 15° E to 50° E. The maximum difference (positive values) occurs at the surface and 850 hPa especially over Egypt and north-east and east of the Mediterranean. There are small negative values in temperature over south-east Egypt, The Red Sea, Saudi Arabia and over the Gulf area.

RELATIVE HUMIDITY (RH)

Figs. 5 and 6 show the distribution of the mean values of RH and its differences from 1998 at 1000 and 850 hPa levels for July and August respectively. The climatological pattern (mean, 1960-2000) illustrate that the maximum values of RH at 1000 hPa occurs over the east part of the Mediterranean and over The Black Sea, exceeds 80 % in July and August. It decreases with height to reach its minimum values at 300 hPa. It is interesting to note that the values of RH over the area east of Red Sea and west of the Arabian Gulf at 500 hPa are greater than that at 850 and 1000 hPa; this is due to the effect of the easterly Jet. Fig. 5b illustrates the difference in RH between 1998 and the mean. Generally, there are small increases and small decreases of RH at different regions.

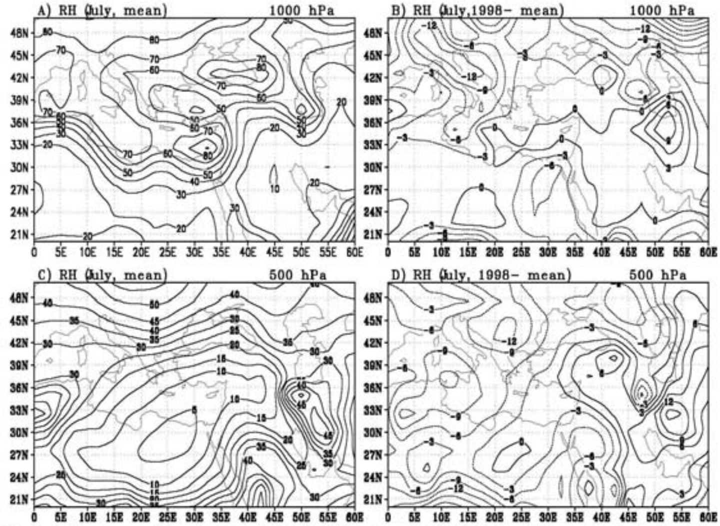

Fig. 5: a) The average RH (1960-2000) for July at 1000 hPa, b) the difference of RH between July 1998 and the average July at 1000 hPa, c) the average RH at 850 hPa level and d) the difference RH between July 1998 and the average July at 850 hPa.

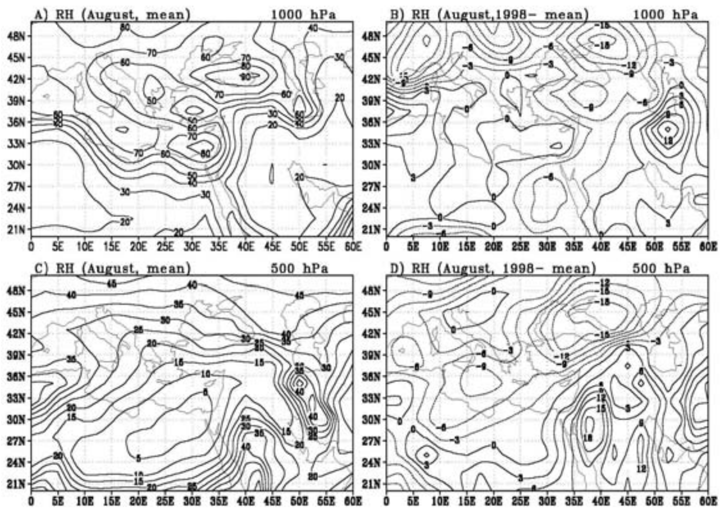

Fig. 6: as for Fig. 5 but for August.

Over Egypt the decrease of RH in 1998 reaches 5 % at most levels. Fig. 6b also shows the difference of RH between 1998 and the average of (1960-2000) for the month of August.

VERTICAL WIND

Figs. 7 and 8 illustrate the horizontal distribution of the average vertical motion (1960-2000) and its differences from 1998 for July and August at 1000 and 500 hPa levels. The most interesting feature is the downward motion over the Mediterranean, north Africa and south Europe, this feature appears at 1000 hPa and is more pronounced at the upper levels for July and August (Figs. 7a,c and 8a,c).

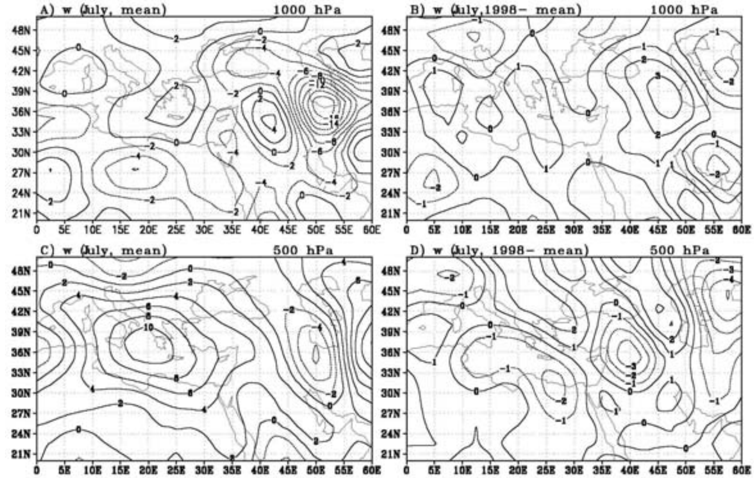

Fig. 7: a) The average vertical motion (1960-2000) forJuly at 1000 hPa, b) the difference of vertical motion between July 1998 and the average July at 1000 hPa, c) the average vertical motion at 500 hPa level and d) the difference of vertical motion between July 1998 and the average July at 500 hPa.

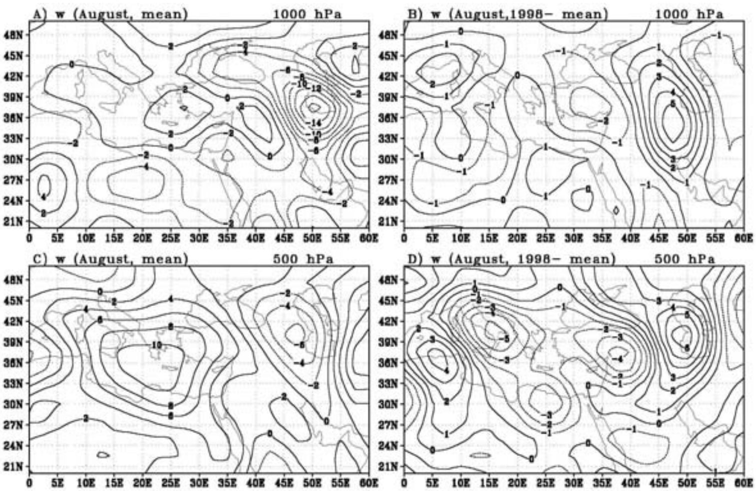

Fig. 8: as in Fig. 7 but for August.

The charts in this paper display that the upward motion over Mediterranean and Egypt decreases during July and August of 1998 than the mean values except at 1000 hPa.

EAST WEST VARIATIONS

East-west variation of height and temperature

The east-west (20 ^{o}W to 60 ^{o}E) vertical cross-sections for the geopotential height and temperature anomalies (1998 mean) for July and August for the latitude belt 20 ^{o} to 40 ^{o}N (not shown) illustrate strong upper and lower anticyclonic anomalies during these months of 1998. The Maximum intensity of the subtropical high pressure over Egypt occurs at August at upper and lower levels. The positive values of height (1998 mean) over the belt 20 ^{o} to 40 ^{o}N and from the surface to 1000 hPa indicate that the year of 1998 was a warmer year.

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These results can be noticed from Figs. 9a, b where the positive values of temperature anomaly occur over the interesting belt and the most levels especially at the lower layer.

The maximum values of positive temperature anomalies (2.5 ^{o}C) appear over Egypt at August at the layer (900- 850 hPa). It also shows that the height of 1998 is more than that of the mean throughout the two months and at all the levels. These results also can be shown from the anomaly of temperatures, it also illustrates that the year 1998 was warmer than the average.

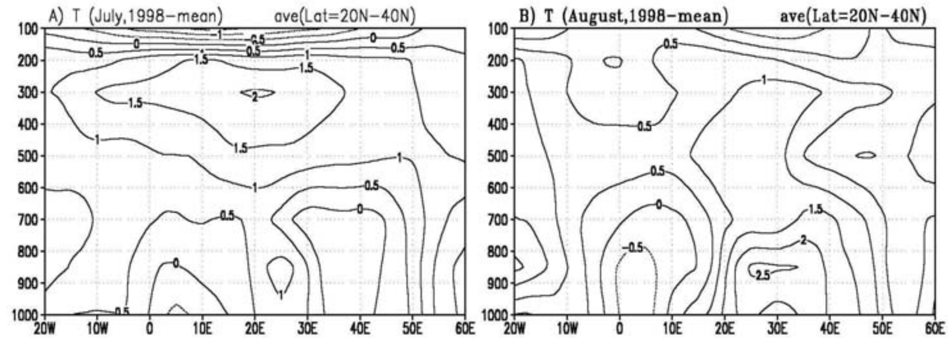

Fig. 9: a) Zonal Vertical cross section of the differences between temperature of July 1998 and average July (1960-2000), b) As in a) but for August.

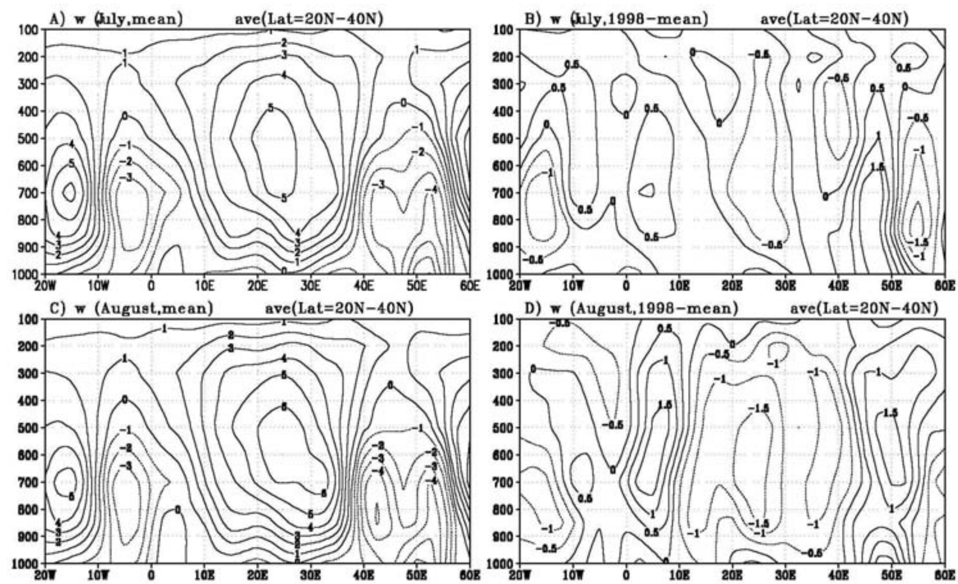

Fig. 10: a) Zonal Vertical cross section of the vertical motion of average July (1960-2000), b) as in a) but for August.

East-west variation of vertical motion

Fig. 10 illustrates the east-west (20° W to 60° E) vertical cross sections for the vertical motion and their differences from the mean for July and August 1998 for the latitude belt 20 ° to 40 ° N. It shows that there are two main features of the mean value field; the first is the upward motion from 40° E to 57.5° E and from 1000 to 500 hPa, while the second is the downward motion from 10° to 40° E from 1000 to 100 hPa. The maximum subsidence occurs between 800-300 hPa and from 20° to 35° E. while the pattern of the mean vertical motion is somewhat similar during the summer months, the pattern of the differences from 1998 is different from month to month. At June (not shown) there is an increase in the downward motion in 1998 from 5 ° to 20 ° E at all levels and from 30 ° to 37.5 °E from the surface to 500 hPa. While this subsidence decrease between latitudes 20° to 30° E and from the surface to 200 hPa. During July the decrease in subsidence occurs between 20° to 32.5° E throughout all levels. The greatest decrease of subsidence in 1998 about the mean appears in August, where the negative values of the vertical motion occurs between 10° to 40° E throughout all levels with the maximum one over Egypt. During September 1998 the feature changed in August but the area from 20° to 30° E still experiences a decrease in downward motion in 1998 than the mean. Fig. 12 shows in a more obvious pattern the strength and direction of upward motion of the mean and 1998 for the July and August months.

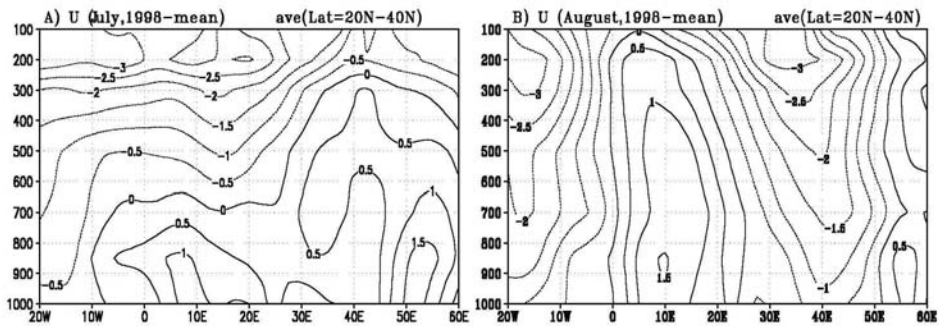

Fig. 11: as in Fig. 9 but for U-component of wind.

East-west variation of the Zonal wind

The results of studying the east-west vertical cross-section for the zonal wind component (u) in m/s for July and August 1998 and its differences from the average for the mean latitudinal belt 20o to 40o N (Fig. 11) can be summarised as follows:

Strong westerly zonal wind was situated over our belt (20o to 40o N) from 20o to 40o E in the upper levels (200 hPa), it was associated with a subtropical Jet stream. The domain of anomaly is divided into two parts, the first part lies west of 40o E is associated with positive anomalies which indicate that the westerly wind in June 1998 was more than that of the mean, the second part (east of 40o E) is associated with negative anomalies.

During July the subtropical Jet is weaker and shifts westward, this can be seen clearly from the negative anomalies of the zonal wind component at 200 hPa.

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During August the Zonal easterly component is weaken from 25^o to 50^o E at the upper levels and also at the lower levels. Also the easterly zonal wind component was weakening; this can be seen from 00^o to 25^o E from the surface up to 700 hPa. In September, the westerly Jet returns to oscillate eastward and intensifies, but is still weaker than the mean at 200 hPa between 00^o to 10 ^{o} E.

East-west variation of RH

Fig. 12 shows the east west vertical cross-section at the latitude 35^o E for the variation from the mean relative humidity from longitude 20^o W to 60^o E for the interested months. It also shows the direction of vertical wind over the same latitude for 1998 and the mean. Generally, it illustrate that the maximum sinking motion occurs between 17.5^o E to 32.5^o E with the maximum RH concentrated in this area from the surface up to 850 hPa. The rising motion occurs between 47.5^o E to 52.5^o E and also between 5^o W to 5^o E, it associated with increasing RH at the upper levels (700-400 hPa). It can be notice that the pattern of rising motion and sinking motion is shifted westward during 1998 from the mean (Fig. 10), and due to this movement of vertical wind the centers of maximum RH at the lower and upper levels also shifted westward over Egypt. These illustrate the increase of maximum sinking air, humidity, temperature and stability that characterise the summer weather of this area.

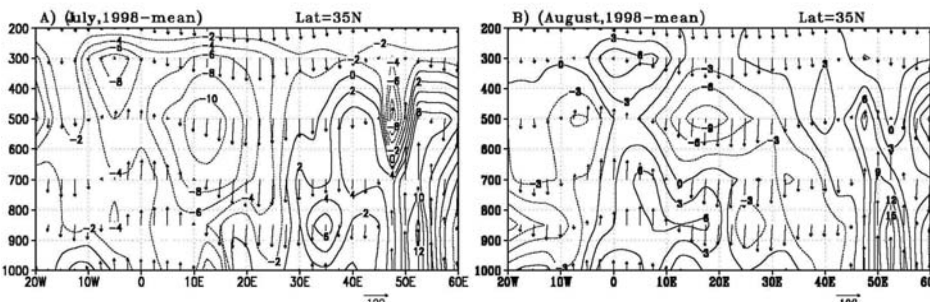

Fig. 12: as in Fig. 10 but for relative humidity.

East-west variation of the meridional wind component

Fig. 13 depict the east-west variations from the mean of the meridional component V, and the pattern of the vertical direction of wind at 35^o E between 20^o W to 60^o E for July and August. First, it is clear that the sinking motion is associated with a southerly V-component while the rising motion is associated with northerly V-component. Secondly, we also notice that the northerly and southerly V-component of 1998 are stronger than that corresponding to the mean during the two months. The maximum differences occur during August where the southerly component reaches more than 6 m/s between 800-600 hPa at 20-22.5 ^{o}E in 1998 while its correspondence for the mean is 2 m/s.

HEIGHT LATITUDINAL VARIATIONS

Fig. 14 shows the meridional vertical cross-section at 25^o E for the pattern of vertical motion. It is clear that the sinking motion is associated with the subtropical Jet around 35^o E while the rising motion is associated with the tropical easterly Jet.

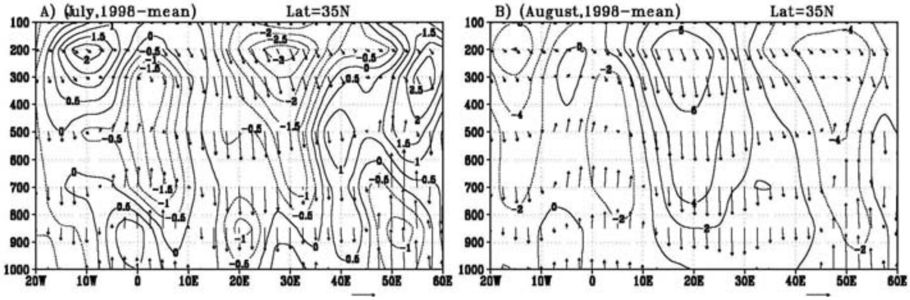

Fig. 13: as in Fig. 10 but for V-component of wind.

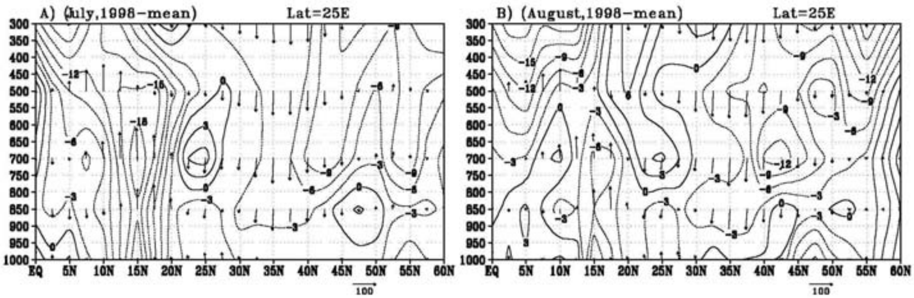

Fig. 14: a) Meridional vertical cross section of the RH humidity of the difference between July 1998 and average July, b) as in a) but for August.

The figure shows a typical Hadley type cell where warm air is rising and cold air is sinking. It is clear that the intensity of rising motion and sinking motion during the months in 1998 (July, and August) is weaker than the average from 1960-2000. Also there is a northward shift of the centres with a sinking and rising motion.

The mean pattern (not shown), illustrates the high increase of RH from the equator to 12.5° N at lower and upper levels associated with the maximum heating and maximum rising motion. While at the latitudes from 20 to 42.5° N the high values of RH are concentrated at the lower levels (surface-850 hPa) associated with the maximum sinking motion. Fig. 14 also shows the differences of RH for the four months between 1998 and the average. It is clear that the year 1998 is not only a warmer year but also is a dry year during the summer months. This can be seen from the negative values in the differences that appear in the vertical distribution of RH. There are only some positive values and these appear between latitude 20° N and 32.5° N and from 800-300 hPa in the first three months. In September the positive values appear between latitudes 32.5° N to 50° N from the surface to 300 hPa. Generally the magnitude of the negative values of the differences is greater than the magnitude of the positive values during the four months, where we found that the maximum negative values at June reaches more than 20 % while the maximum positive values reaches 10 %. In July the maximum negative values reaches 18 % while the maximum positive value is 6, this feature can be also seen in August and September.

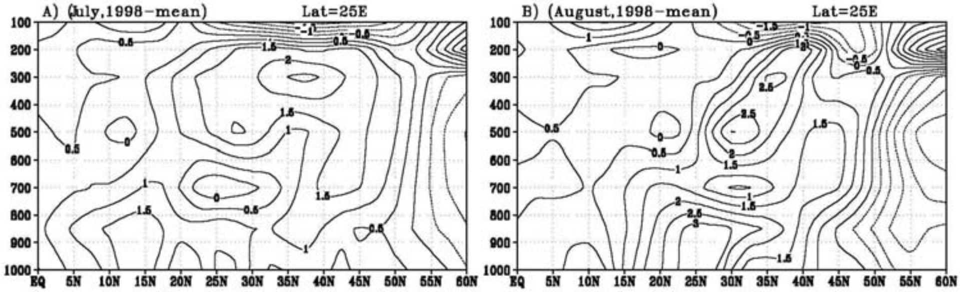

Fig. 15: a) Meridional vertical cross section of the temperature of the difference between July 1998 and average July, b) as in a) but for August.

Fig. 15 illustrates the meridional vertical distribution of the differences in temperature in 1998 from the average for the two months. It shows that the maximum surface temperature occurs between longitude 12.5 and 25° N, and the minimum surface temperature at the pole. It also illustrate that in general the summer months of 1998 were warmer than the average, especially in August where the differences reaches 3 °C between 15° N to 30° N and from the surface to 200 hPa. The only negative values appear in June between 20° N and 40° N and from 700- 200 hPa.

CONCLUSION

During the summer of 1998, the Mediterranean area is subject to episodes of air temperature increase, which are usually referred to as "heat waves". These waves are characterised by a long lasting duration and pronounced intensity of the temperature anomaly. We used NCEP/NCAR data in analysing and investigating the causes of this summer heat wave. The most significant findings were as follows;

A) The subtropical height pressure system is weaker during 1998 and is seen to be mainly to the east of its climatological position, so the extension of the Indian monsoon low oscillates to the west more than its average position.

B) The pattern of rising motion and sinking motion is shifted westward during 1998 from the mean and due to this movement of vertical wind the centres of maximum humidity at the lower and upper levels are also shifted westward over Egypt. These illustrate the increase of maximum sinking air, humidity, temperature and stability that characterise the summer weather in this area.

C) The increase of temperature during the summer of 1998 was shown to be due to the increase of the subsidence of: 1) the branch of the local tropical Northern Hemisphere Hadley cell; 2) the branch of the Walker type over the Mediterranean sea and North Africa; 3) the steady northerly winds between the Asiatic monsoon low and the Azores high pressure.

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