THE RECENT HEATWAVES OVER BALKANS AS AN INDICATOR OF CLIMATE CHANGE AND A SIGNAL FOR NEW PLANNING DECISIONS

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ABSTRACT The appearance of heatwaves on the Balkan Peninsula is a phenomenon that caught the interest of scientists over the last 20 years. The first heatwave appeared in Greece in July 1987. In the following years a frequent presence of heatwaves is observed was also studied by various researchers. The detailed study of heatwaves shows that to they are caused by the transport of hot air masses from Africa. These masses are characterized by a large atmospheric thickness. The analysis reveals that the transport of African hot air to regions far north of the equator is driven by a shift to the pole of the subtropical jet stream, which coincides with the behaviour of the Hadley cell. In summer 2007 three heatwaves occurred which were characterized by larger geographical extension. These heatwaves extended much further north covering large part of Bulgaria, Serbia, Romania, part of Asia Minor and southern Italy. The weather conditions that prevail in these regions during the heatwaves are analyzed in detail. It is realized that, in these cases, the subtropical jet stream was shifted much further north compared with the areas that were affected by previous heatwaves. This evidence shows that a new dynamic in the atmospheric circulation has developed which leads to strong fluctuations of the Hadley cell, with shifts of the cell much further north. All these processes are clearly a result of the high energy amounts that concentrate over the tropics. An increase in the energy budged in the tropics finally leads to more intense disturbances of the tropic atmospheric circulation. A first indication for this is the higher frequency of hotter summers on the Balkan with serious impacts on health, energy consumption agriculture, irrigation, transportation, tourism and other fields.

KEYWORDS: *Heat waves, Balcans, Climate change*

INTRODUCTION

The first heatwave ever recorded in Greece had reached the country in July 1987 (Giles and Balafoutis, 1990). The affected area was delimited over the Greek peninsula with the most unfavorable weather conditions in the two larger urban areas of Athens and Thessaloniki. This heatwave was responsible for the death of more than 2500 people. In the following year, on

August 1988, a new heatwave stroke again in Greece. This time, the influences on the human bodies were much less severe as the Greek government had set up a system to deal with the heatwave impacts.

Since then, heatwaves have become a common summer phenomenon in Greece with many occurrences over the next decade. Until the end of the 20th century, the heatwaves concentrated geographically on the Greek peninsula. In August 1999, another strong heatwave stroke Greece (Balafoutis and Makrogiannis, 2000) but did not affect the public, as until then the public offices, busses, trains and many houses were air-conditioned. The same heatwave impact also happened in Greece in 2000.

At the beginning of this century the dimensions of the heatwaves changed dramatically as the heatwaves increased in frequency, in geographical extension and also in severity. At this point the heatwaves were no longer only a Greek problem. During the period 6-12th August 2003 a heatwave with very high temperatures (records in many cities) stroke Western Europe and especially France, where about 15000 people lost there life due to the sultry conditions owed to this weather phenomenon.

After the year 2000, the heatwaves over Greece appeared more frequently. Some of them were weak and did not attract the attention of researchers but others were very strong and required further scientific attention. In this paper we will concentrate our interest on a number of heatwaves that stroke Greece during the summer of 2007 as they were characterized not only by very high temperature records, but also a very large geographical area that extended from southern Italy, all of Greece, almost all of the Balkan countries up to the Crimea peninsula and the Asia Mirror (Fig. 2, left).

This geographical extension of the heatwaves, which were characterized by very high temperatures of up to 47 °C, indicates that more warm summers are to come in the Mediterranean area. This exhorts the authorities to change the strategy with regards to health protection, transportation, agriculture, energy production and consumption, water resources and also tourism.

In the following paragraphs, the causes and consequences of these heatwaves will be analysed.

THE HEATWAVES OF SUMMER 2007

a. The definition of a Heat Wave

According to the international literature there is no strict definition of the term "heatwave". According to the Robinson (2001), a `heatwave' is an extended period of unusually high atmosphere-related heat stress, which causes temporary modifications in lifestyle and which may have adverse health consequences for the affected population. The NWS (1994) uses criteria based on surface temperatures and heat index values (HI) in relation with the time duration (at least 48 hours) and geographical extension of the phenomenon. These definitions are not able to describe the area which is going to be affected by the heatwave.

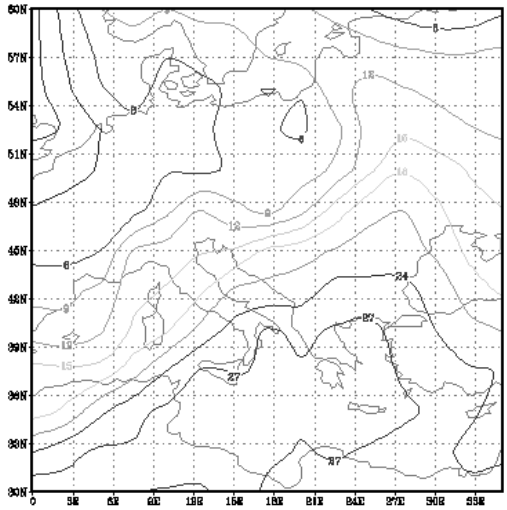

Figure 1: The air temperature at 850 hPa over East Mediterranean (26-06-2007)

As a heatwave has a very close relation with the upper air circulation and the weather forecast is based on upper air charts, the air temperature distribution at the level of 850 hPa will be used in this paper to define heatwaves. When the air temperature at this level is greater than 21 °C, and these conditions last for more than two days, the underlying surface will suffer from a heatwave invasion.

This definition of heatwaves has the advantage that the entire area that will be affected by the heatwave is recognised. The isotherm of 21 °C remarks the limits of the heatwave zone. This definition is valid for latitudes up to 45° N. Further north the limit of 20 °C is considered as more appropriate (Fig. 1).

b. Analysis of heatwaves

During the summer 2007 a large part of the eastern Mediterranean experienced three heatwaves. The first heatwave appeared in June (20-28th). This is the earliest ever recorded heatwave as until this time heatwaves were common only in July or August. The second of them appeared in July (18-26), and the third with shorter duration and extension in August (21-25). The last one was weak and geographically limited to Greece and was not so important for this analysis.

The June heatwave is very significant as it adds another dimension to the heatwave action. June is usually a month that is characterized by comfortable temperatures, especially in Greece, and very high temperatures appear only once or twice during this month, but not every summer. In June 2007 an overturning of the temperature regime was recorded over the Balkans with very high temperatures in the entire area. In Fig. 2, left, the distribution of the maximum air temperature, which was influenced by the heatwave and recorded on June 26th is shown. Similar conditions were common for many consecutive days resulting in adverse health effects. This area of high temperature is in absolute accordance with the area on Fig. 1, confirming the validity of the above given definition. Another important ascertainment is that during the heatwaves the night temperatures stay very high, resulting in stress conditions also during the sleeping time (Fig. 2, right), as the minimum temperatures in many places range from 25 to 28 °C.

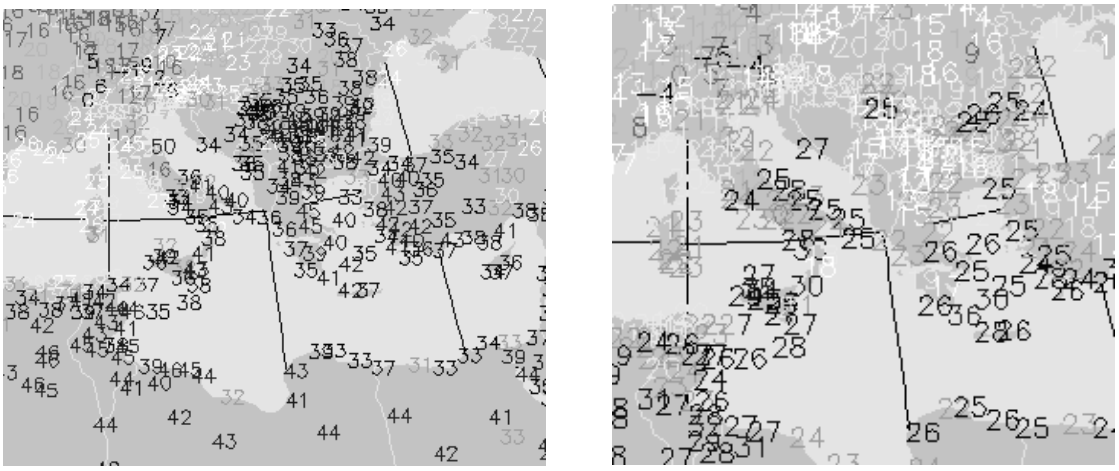

Figure 2: The distribution of the maximum (left) and minimum (right) air temperatures on 26-06-2007

Important information is given on the analysis of the upper air circulation during the heatwave period. At the level of 500 hPa (Fig. 3, left) it is manifested that a ridge of hot African air lies over the studied area. The winds are moderate following the contour lines, but a strong subsidence dominates, as relevant upper air graphs had shown.

At the lower level of 850 hPa (Fig. 3, right) the main feature is the wind circulation which appears like a close Vortex. This system results in hot northerly surface winds in many places, which causes the feeling of people that the heatwave comes from the north!

The analysis outlined above focuses on the heatwave in June 2007. For July we will see that another heat wave similar to the one previously described affected the same area. Also, this new heatwave was characterized by very high temperatures and a long duration of about 10 days.

As it was mentioned above that the main cause leading to heatwave formation is the circulation in the upper atmosphere. In a previous study (Balafoutis and Makrogiannis, 2000) it was pointed out that the cause is the behavior of the subtropical jet stream.

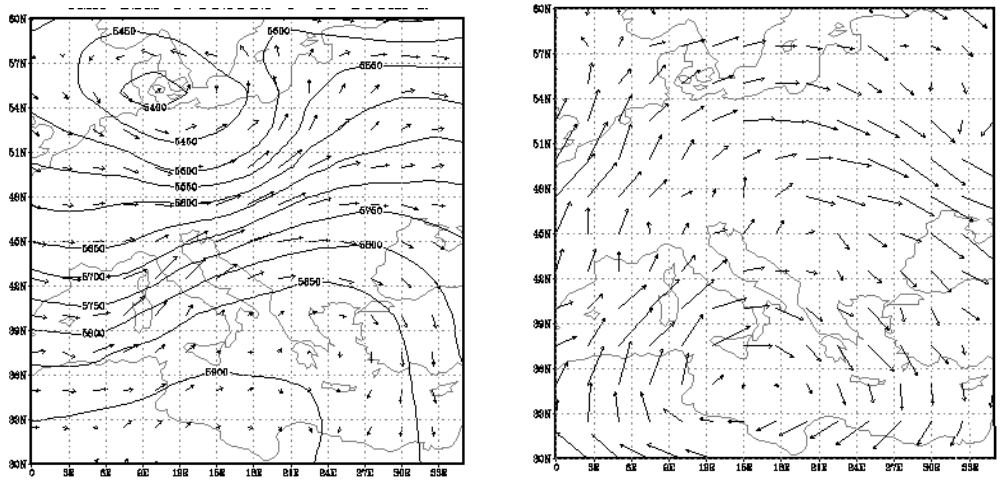

Figure 3: The atmospheric circulation at 500 (left) and 850 hPa (right) on 26-06-07

The subtropical jet is located exactly at the northern upper end of the Hadley cell. Few days before the heatwave appearance, this jet stream was displaced far north and became too weak, giving free space to the hot African air to move towards the Balkans. That means that the Hadley cell was shifted further north. In Fig. 4, the atmospheric circulation at the level of 200 hPa - the elevation of the summer jet stream position - makes evident that an intense African ridge covering the Balkans is present in this height, coinciding with weak southerly winds in that area. The strong jet winds are displaced far north and do not affect the studied area.

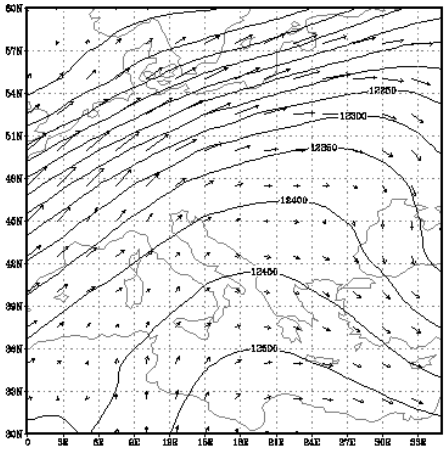

Figure 4: The atmospheric circulation at 200 hPa (18-07-2007)

This event happened on July 18th, which means that this date marks the onset of the heatwave. This information is very important and the forecast of heatwaves should focus on the fluctuations of the subtropical jet stream many days before a heatwave event.

c. Maximum Temperature records

The distribution of the maximum air temperature is given on Fig. 2, where it is obvious that the heatwaves brought very high temperatures. Looking at Greece it is worth mentioning that during this period new temperature records were achieved in many places. Thus in Athens the

highest recorded temperature was 46.2 °C (at a suburb station) on June 26th. In northern Greece the town of Serres recorded 44.6 °C on July 25th and on Corfu Island the temperature was rising up to 42.8 °C on July 24th. But similar high temperatures were recorded in many Balkan cities which are located far north of Greece, as the graphs on Fig. 5 show. In order to have a better view of the heat wave intercity and the geographical distribution of high temperatures, graphs showing the maximum temperature course from June 5th to July 31st for selected stations located near the edges and the core of the entire area are presented. These graphs are from the site: *www.weatheronline.co.uk*.

All graphs on Fig. 5 have two remarkable peaks of maximum temperature. The first of them corresponds to the June heatwave and the second to the July one. The fist graph (top left) corresponds to Bari-Italy, on the southwest edge of the affected area, shows that in both cases the maximum temperatures were above 45 °C. Larissa (top middle) is a representative station for the conditions that prevailed in the Greek Great Plains. The graph in the top-right shows data for Antalya-Turkey with temperatures above 44 °C for many days. In Belgrade (graph down left) only the July heatwave was noted with temperatures of up to 44 °C. In northern Bulgaria, at Rousse (down middle), both heatwaves were pronounced. Finally, the heatwaves were present in the far north located Bucharest (bottom right).

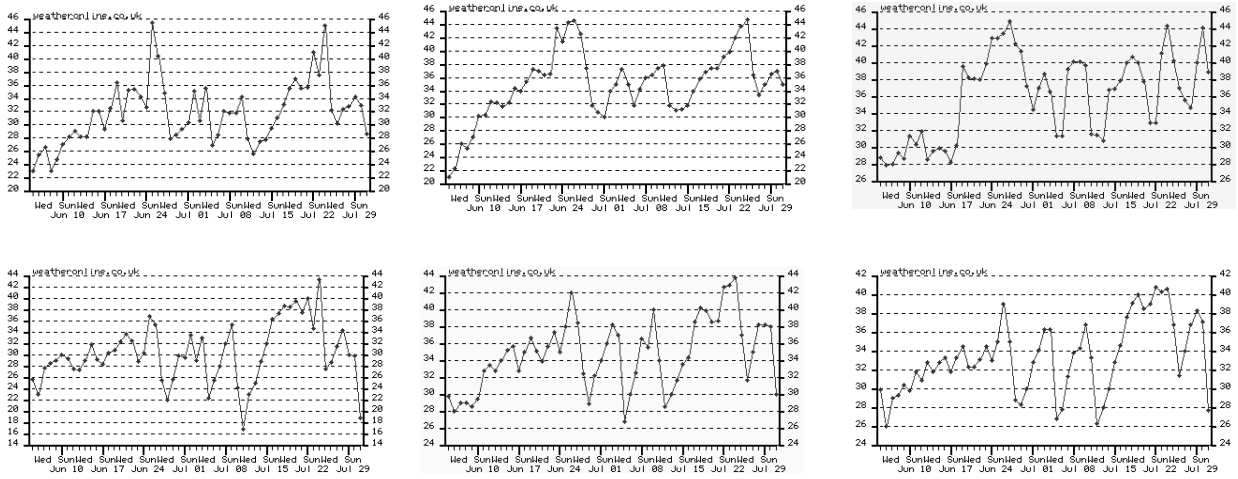

Figure 5: Maximum temperature course, in selected stations during June-July 2007 (from left to right) Bari, Larissa, Antalya, Belgrade, Rousse, Bucharest

Considering these temperature graphs it is evident that certain areas are more prone to heatwaves than others. In the following graphs (Fig. 6) this ascertainment is confirmed using the temperature course on the Aegean Islands Rhodes (left) and Naxos (right). When comparing these temperatures with those in Fig. 5, it becomes clear that temperatures in

popular tourism areas are remarkably cooler with 35 to 37 °C during the peak of the heatwave.

It is very important to mention that during the heatwave the atmospheric humidity remains at low levels as a combination of high temperature and humidity is almost lethal. The low humidity values are the result of the adiabatic subsiding mechanism, which acts in the upper atmospheric ridge affecting the influenced area.

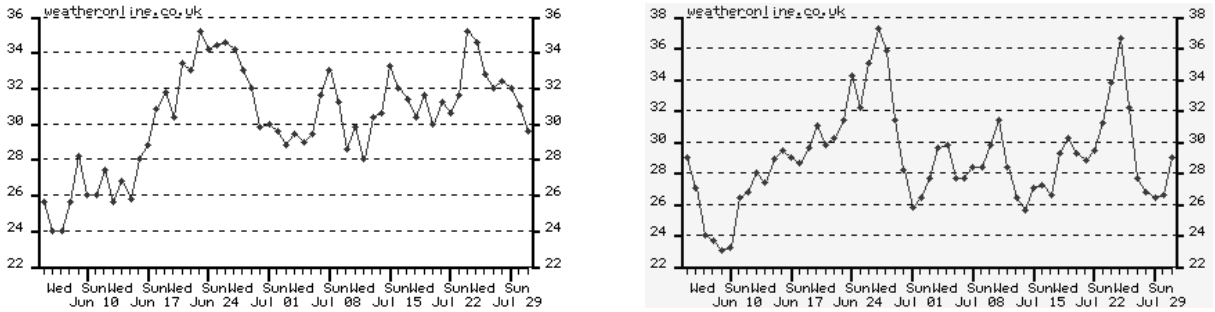

Figure 6: Maximum temperature course in Rhodes (left) and Naxos Islands (right)

The analysis presented above showed that the entire area had experienced very high temperatures that brought a lot of significant problems to the population, cultivation, water reservoirs, and tourism. These problems were further intensified in 2007, as the summer was characterized by a lack of precipitation. A shortage in the vegetable production was remarkable during the heatwave and the prices increased as the high temperatures exert negative influences on plant growth.

Furthermore, the heatwave had serious impacts on the electricity consumption. For example in Greece, these high temperatures had pushed demand for electricity to new all time heights, as Greeks tried to stay cool in air conditioned homes and offices. These demands were very close to the total ability of the country to produce electricity.

Finally, the June searing heatwave killed about 50 people across southern eastern Europe but only four elderly in Greece died as the country had prepared for a heatwave like this one.

CONCLUSIONS

Throughout this work we have discovered that the impacts of extreme high temperature are both severe and widespread. With the threat of climate change, the need to understand heat waves, their origins and their effects become even more relevant. The definition of a heat wave using synoptic weather maps at 850 hPa-instead of surface data is more convenient as it can characterize the entire area which will potentially be affected by a heat wave. The 200 hPa level is a good indicator for an imminent heatwave. The June 2007 heatwave showed that

strong heatwaves can come earlier in the beginning of the summer and not only during the hottest months July and August. The remarkable finding of this study is that these heat waves hade a large geographical extension covering an area that until now had not any experience with heat strokes and the people were not ready to be confronted with disasters of that kind. These heatwaves have had a broad and far-reaching set of impacts on the area. These include significant loss of life, economic cost of transportation, agriculture, energy production and also cancelling of programming arrivals of tourist groups.

The repetition of the heatwave in July was a warning signal that due to climate change the future summer conditions will be worse with severe influences on humans.

Or results send a warning to the authorities that it is time to make plans to manipulate the climate crisis.

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