ANALYSIS OF A HEAT WAVE PHENOMENON OVER GREECE AND IT'S IMPLICATIONS FOR TOURISM AND RECREATION.

By
Ch. J. Balafoutis and T.J. Makrogiannis
Department of Meteorology and Climatology
Aristotle University of Thessaloniki - Greece

ABSTRACT
As it is known the climatic conditions is a very important one when someone planning a holiday in a certain country. Especially the analysis of extreme weather events helps the tourism ,in general , very much. In this paper the heat wave phenomenon over the mainland of Greece, during the days 18 to 21 August 1999, has been studied mainly from a synoptic point of view. The predominant synoptic conditions at the surface was an anticyclonic flow contributing positively to transfer Tc air masses from Sahara desert to Greece. SW flux was predominating into layers of the middle troposphere. This type of circulation gives an intensive negative vorticity in the middle troposphere and a warm advection in the lower troposphere, over the studied area. Meanwhile the main axis of the Subtropical Jet Stream, at 200-hPa level, was displaced far north from the Balkans with a maximum wind speed of 100 Knots. Beneath the jet stream and south of its axis, was taking place a large-scale subsidence. This downward flow of troposphere air contributes in a warmer advection, because of the adiabatic heating. That was actually, the 'key' synoptic system for the heat wave phenomenon, during these days, which is a very important element for the heat wave prediction over Greece.

INTRODUCTION

As it is known the heat wave is a meteorological phenomenon that consists from an abnormally hot and usually humid weather. This phenomenon belongs to the atmosphere's synoptic scale circulation.

During the period 18 to 21 in August 1999, over the hinterland of Greece the weather was very hot, a phenomenon that usually is called Heat Wave. This was a front-page title in many Greek newspapers and the Public Authorities had taken preventative measures. According to the international literature there is not a strict definition of the term "Heat Wave". In the Greek literature, Metaxas and Kallos (1980), refer to this term when the following criteria take place:

a) The maximum temperature in Athens Observatory must be at least 37 °C.

b) The average daily temperature must be at least 31 °C, at the same station.

c) The maximum temperature at Larissa station must be at least 38°C on that day.

In USA, the Weather Channel uses the following criteria in order to specify a Heat Wave invasion:

a) A minimum of ten States with maximum temperatures greater than 32°C and
b) The temperatures must be at least five degrees above normal in parts of that area for at least two days or more.

In order to study this phenomenon we have used a combination of the above definitions.

The main target of this paper is to give the Synoptic Situation, as well as the Physical processes during this period over the major Greek area.

Only a few scientists, Giles and Balafoutis (1990), Metaxas and Kallos (1980), Prezerakos (1989, 1998), Karakostas and Gawith(1994), Karakostas et al (1996) have been studied this heat wave phenomenon over Greece.

DATA AND METHOD USED

In order to have a detail information about the Synoptic Structure and an Analysis of the atmospheric circulation, we have used a lot of information given by the NOAA Air Resources Laboratory in the web site:

http://www.arl.noaa.gov/ready/disclaim.html

More specifically, from this web site the following maps and graphs have been used: Maps of temperature values at the surface and at the level of 850 hPa, weather maps with wind speed values (Knots) at 200 hPa level, weather maps of wind flags at the levels of 500 and 850 hPa, the w-wind component weather maps at 700 hPa level and the Potential Temperature graphs.

SYNOPTIC SITUATION AND ATMOSPHERIC CIRCULATION ANALYSIS

The synoptic experience for the heat waves indicates that the “Key” for their appearance is the position of the Subtropical Jet Stream (STJ) in the upper troposphere.

When the meteorological conditions during the summer over the Mediterranean and especially over the Greek area are normal, the main position of the STJ is observed over the following areas: SW Spain, Sicily, South of the Greek peninsula, Central

Aegean Sea and SW Turkey (Prezerakos, 1978). The axis of the maximum wind speed is located at the 200-hPa level.

The synoptic experience also indicates that: when this STJ moves north of the Greek area, the meteorological conditions in Greece are abnormal and their main characteristic is the very high values of the surface air temperatures. That is the Heat Wave phenomenon. The northern of Greece the STJ is located the more intense is the heat wave strike.

In Figure 1, the geographical distribution of the air temperature, at a level of 2 m above the ground is portrayed. As we can see from these isotherms, during the days of the phenomenon, the temperature values at 12 UTC (15 LT) were more than 32 °C over the whole Greek peninsula and also over Turkish hinterland.

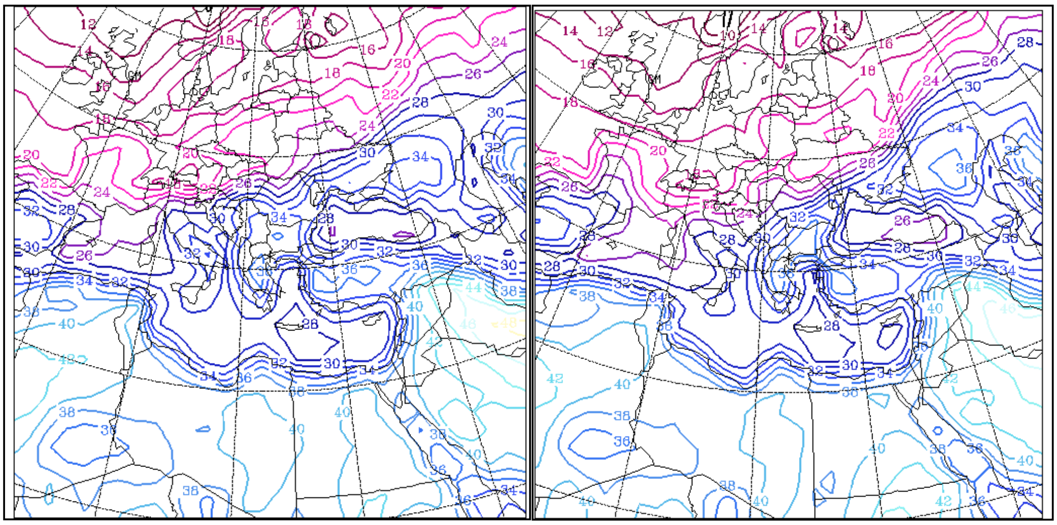

Fig. 1 Air temperature distribution (at 2 m) on 20 and 21-08-99 (12 UTC)

Meanwhile, the maxima of air temperatures in the main cities of Greece were:

City\Date	18	19	20	21	22	23
Athens	36.7	37.2	40.8	39.4	39.9	34.6
Larissa	37.4	38.8	39.6	40.6	35.8	36.1
Thessaloniki	34.5	35.4	37.8	36.6	35.5	33.0

According to the above mentioned criteria these days can be characterized as Heat Wave days over the continental area of Greece.

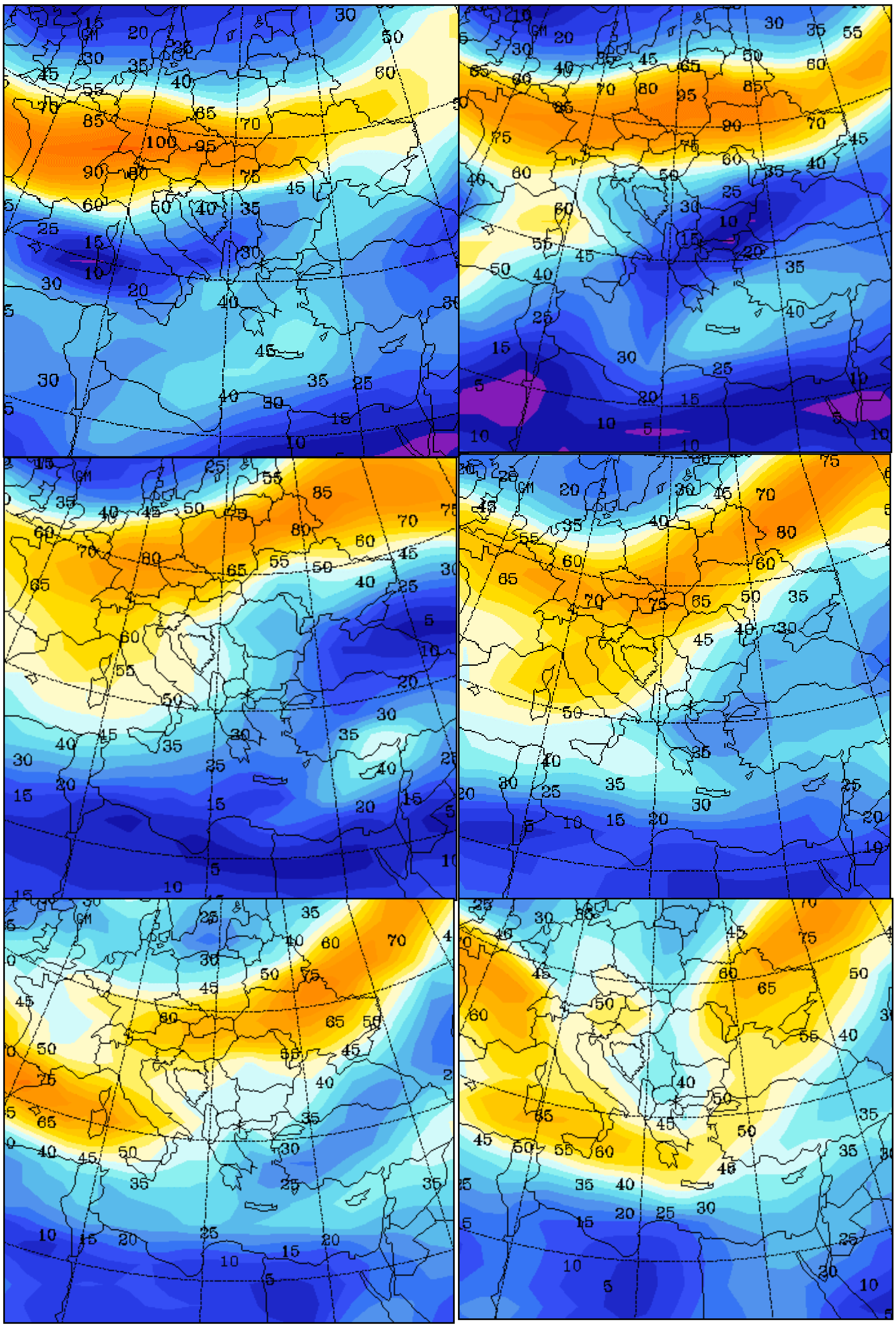

Fig. 2 The wind speed field and the positions of the Subtropical Jet during the period 18 to 23, August, 1999, at 200 hPa level (from top left to right down).

In Figure 2, the positions of the STJ, during the period 18 to 23 of August 1999 at 00 TC, are portrayed with a maximum wind speed of 100 knots. As we can see, during the main days of the appearance of the phenomenon (18-21 August) the axis of the STJ is actually far northward of the Greek area, but after the end of the phenomenon this axis moves southward and on 23rd of August it returns, as far as it concerns the Greek area, in the main position that it usually holds during the summer season and which characterizes normal weather conditions in that area.

Moreover the physical process that takes place under these synoptic conditions is the large-scale subsidence within the tropospheric air down and south of the STJ which leads to the following results:

a) raise of the air temperature due to the adiabatic compression,
b) surface horizontal divergence of the vertical flux, and
c) Increase of the Sea Level Pressure enchasing the anticyclonic circulation and hot weather.

According to the above statements, with such physical processes, the three terms of the right hand side of the thermodynamic equation (Wiin – Nilsen, 1973) bellow,

$$\angle T/\angle t = (1/c_p).(dq/dt) -(\vec{V}.\vec{\nabla}T)o+ \vec{\omega}(\Gamma_d-\Gamma)$$

finally contribute positively, giving a positive value in this equation, i.e. $\angle T/\angle t > 0$.

In other words, this procedure of the large scale subsidence in relation to the horizontal movements from South sectors are responsible for the Heat Wave phenomenon.

In this point it is reminded that the STJ commonly is located at the northern edge of the Hadley Cell (Chandler, 1979) where, as it is well known, the large scale subsidence of the air is observed. This subsidence contributes also to the formation of the Subtropical High Pressure Systems.

The northwards shift of the STJ contributes to the simultaneous movement of the Hadley Cell to the same direction. This means that the axis of the descending movements in the tropospheric air , is now observed over geographical areas with latitudes 35° - 40° N, instead of the usual position located over the parallel of 30°N.

Analyzing the type of the circulation at 500 hPa level (Figure 3) it is observed that a maximum of heights (5950 g.p.m.), centered over Tunisia, results to a SW flux over the west Mediterranean, W flux over Italy and NW or N fluxes over the major Greek area. This type of circulation gives an intensive negative advection of relative vorticity in the middle troposphere and warm advection in the lower one over the studied area.

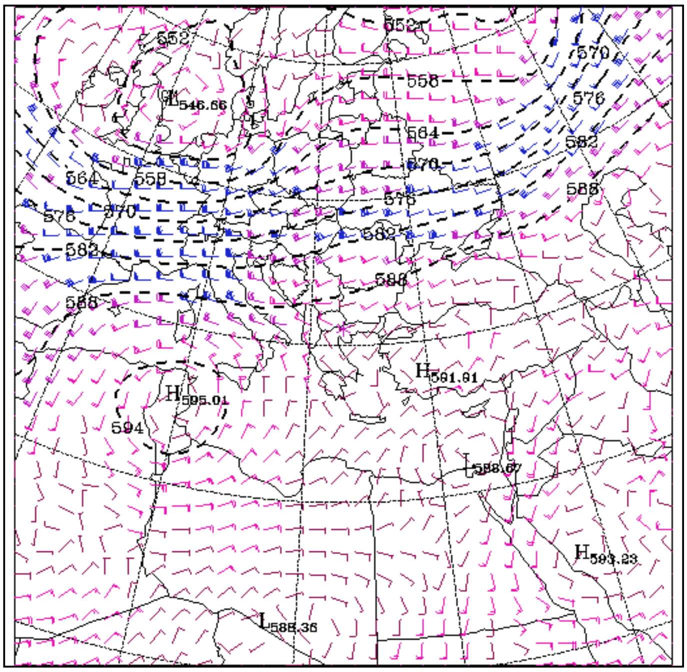

Fig. 3 The wind flags and height contours at 500 hPa level, on 19-08 -99 (00 UTC)

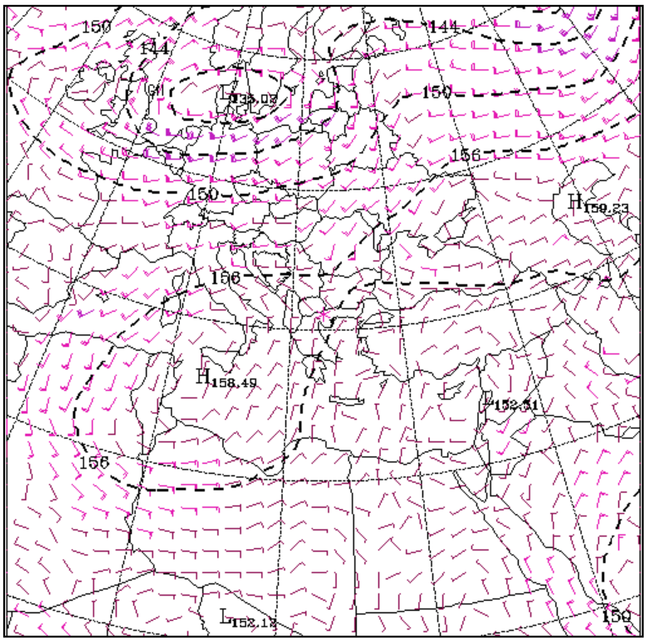

Fig. 4 The wind flags and height contours, at 850 hPa level, on 19-08 -99 (12 UTC)

This warm advection has been seen more clearly in the circulation type at 850 hPa level (Figure 4). This anticyclonic flow transfers very warm and very dry air from Sahara, towards the studied area. So the isotherm of 27° C covers the major part of Greece on the 21^{st} of August (Figure 5).

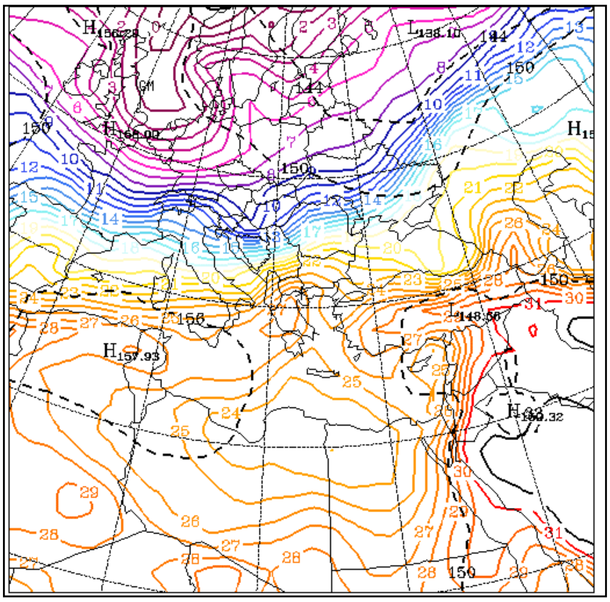

Fig. 5 The air temperature field, at 850 hPa level, on 21-08-99 (12 UTC)

Meanwhile, large scale downward vertical velocities (maximum value +4 hPa/hr) dominate over central Mediterranean and Balkan peninsula (Figure 6). This subsidence, as was mentioned above, contributes to the observed intensive temperature rise at the surface and the absolute stability in the troposphere. This can be seen from Figure 7, where the Potential Temperature (θ) versus height is plotted. A line sloping to the right ($d\theta/dz>0$) indicates absolute stability or an inversion (Heffer, 1983).

CONCLUSIONS

The type of circulation in the middle and lower troposphere, described above, and the corresponding physical processes lead to the following results:

The Heat Wave phenomenon, appearing over the major Greek area, during the period 18 - 21 of August 1999, has been created by the following physical processes. The main axis of the STJ (at 200 hPa level) was located far north of Greece, with maximum wind speed

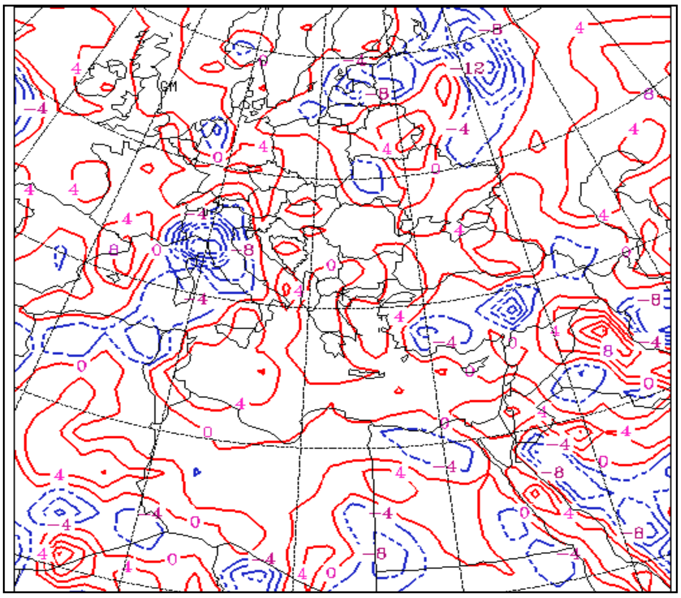

Fig. 6 Vertical velocities (w), at 700 hPa level, on 20-08-99, in hPa/hr (12 UTC)

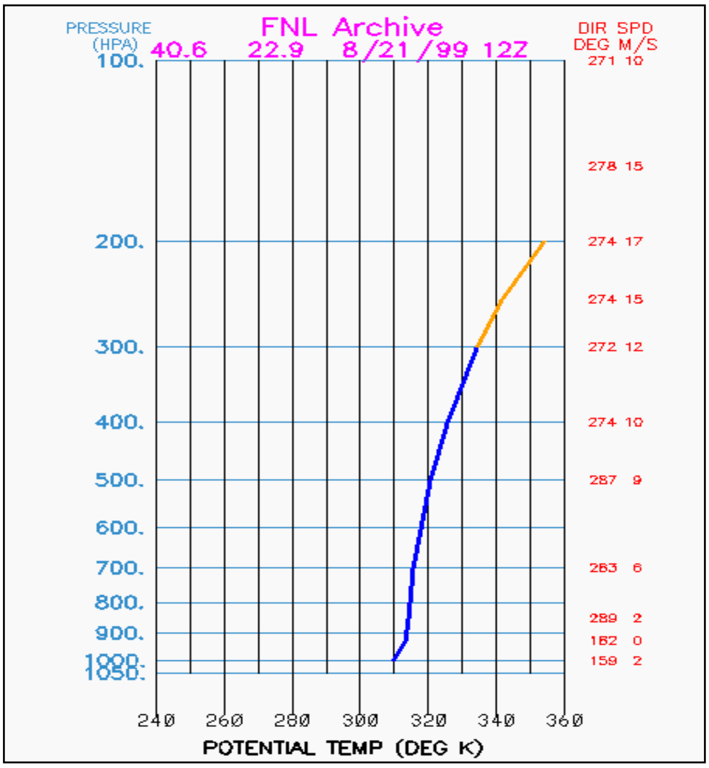

Fig. 7 Graph of the Potential Temperature versus height, on 21-08-99 (12 UTC)

of 100 Knots. It is obvious that this northward shift of the STJ is the "Key" of this special phenomenon, because: It is followed by a simultaneous northward sifting of the Hadley Cell, the upper branch of which is characterized by a broad scale subsidence during these days and is located over areas with a latitude of 35-40° N.

The tropospheric air, above these areas, is warmed up significantly, due to the adiabatic compression. Simultaneously, the circulation type in the middle troposphere ensures a SW flux with negative relative vorticity and warm advection over the studied area.

The synoptic conditions at the surface contribute to the transportation of Tc air masses from Sahara direct to the Greek area. Thus the thermal field over Greece increases significantly, leading finally to the Heat Wave phenomenon.

REFERENCES

Chandel, T.J., 1979: Modern Meteorology and Climatology. Thomas Nelson and Sons Ltd, pp89.

Giles, B.D., and Balafoutis, Ch. J., 1990: The Greek Heat Waves of 1987 and 1988. Int. Journal of Climatol., Vol. 10, p 505-17.

Heffer, J.L., 1983: Branching Atmospheric Trajectory (BAT) Model, NOAA Tech. Memo. ERL ARL-121, Air Resources Laboratory, Silver Spring, MD 20910, 16pp

Karakostas, T.S., Pennas, P.J., and Mitas, C.M., 1996: On the study of Heat Wave events in Thessaloniki, Greece, during the last 30 years. 14th International congress of Biometeorology, Liubljana, Slovenia, 72-79.

Karakostas, T.S., and Gawith, M.T., 1994: Heat Waves in a changing climate, 53-60. In Climate Change and Extreme Events. University of Oxford pres. 125 pp.

Metaxas D.A., Kallos, G., 1980: Heat waves from a synoptic point of view. Rivista di Meteor. Aeronautica. JL, 2-3, 107-19.

Prezerakos, N.G., 1978: Contribution to the study of blocking over the Greek area. (PhD thsis, Univ. of Thessaloniki), in Greek.

Prezerakos, N.G., 1989: A contribution to the study of the Extreme Heat Wave over the South Balkans in July 1987. Meteor. Atmos. Phys. 41, 261-271.

Prezerakos, N.G., 1998. The conditions of atmospheric circulation iv connection with the position of SBJ over the Greek area during the summer. Proceedings of the 4th National Congress in Met-Clim. September, Athens.

Wiin-Nielsen, A., 1973: Dynamic Meteorology. WMO-No 364,367pp, Geneva.

ACKNOWLEDGES: We would like to acknowledge the Atmospheric Research Laboratory of NOAA, for all the graphs that have been taken from there web site.