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HIGH RAINFALL AMOUNTS OVER W GREEK MAINLAND DURING DECEMBER AND JANUARY

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Technical Report No

Presented at the
1rst Hellenic-British Climatological meeting
Athens 5-11 September, 1980

S U M M A R Y

Some synoptic characteristics during the cases of high precipitation amounts over the W mainland of Greece, are studied. The discharge of the Acheloos and Arachthos rivers, monthly and dayly, are taken as an index of horizontally integrated precipitation amounts.

On monthly basis, the mean surface pressure and anomalies from 1900-1972 average are computed, for both, the lower and upper quintile of the discharge amounts of the Acheloos river (seven cases for each month, January and December):

(1) During the lower amounts, a very deep and significant Icelandic low persisted. A high circulation index prevailed over the NW Europe and positive anomalies, most probably a blocking anticyclone, is significant also over about the Balkans.

(2) During the higher discharge amounts, the Icelandic low is weak and/or Southerly displaced. The cyclone tracks appear also displaced south of its normal position.

(3) The above conclusions appear clear and typical in January. In December, a blocking situation may have persisted in most occasions.

On dayly basis, the D-day is at first defined, as the day when a rapid increase of the discharge amount is at first observed in Acheloos and Arachthos rivers, reaching and surpassing subsequently $700 m^3 sec^{-1}$ and $400 m^3 sec^{-1}$ correspondingly (mean 24h amounts). Mean charts for surface pressure, 500 mb and 1000/500 mb thickness, along with their anomalies from 1950-1972 average, are drawn (25 cases in December and 18 cases in January), for 9 days: for the four days before, the D-day and up to D+4 day.

The following conclusions are reached:

1. Main center of action is a deep low which moved very slowly along a track from W Europe up to the Balkans. Its max-

imum strength appeared on about tne D day.

2. Strong SW winds prevailed over Greece, causing a warm advection over this area. Cold advection then followed with a cold front passage, on about the D+1 day.

3. Superposed epoch analysis of rainfall, from D-4 to D+4, for various stations in Greece, showed that the maximum intensity appeared during D day, as in the lower stations of N Greece. But the amount in highland stations is about 2 times larger than the one in low stations in W Greece and 5 to 10 times in the stations E of Pindos mountainrange.

Analysis of the temperature in different levels over the Athens airport showed that, during D-1, D and D+1 days, significant warm air masses prevailed.

Finally, the significant discharges of these rivers, except for an amount that is due to melted snow, is caused by heavy rainfall which starts before D-1 day, with the maximum intensity on D day. Large part of the rainfall appears on the warm sector of the low and is caused by motions due to orography in conjunction with potential instability, usually prevailing over the Mediterranean.

Π Ε Ρ Ι Λ Η Ψ Η

Μελετῶνται μερικά συνοπτικά χαρακτηριστικά τῶν συστημάτων πού προκαλοῦν ἰσχυρές μηνιαῖες καί ἡμερήσιες βροχοπτώσεις στή Δυτική ἠπειρωτική Ἑλλάδα. Δείκτης γιά τίς βροχοπτώσεις αὐτές θεωρήθηκε ἡ παροχή τῶν ποταμῶν Ἀχελώου καί Ἀράχθου.

Γιά τά μηνιαῖα ποσά, παρασκευάστηκαν μέσοι μηνιαῖοι χάρτες πιέσεως, γιά τίς περιπτώσεις τοῦ ἄνω καί κάτω πεμπτημορίου τῶν παροχῶν (ἑπτά περιπτώσεις γιά κάθε μῆνα, Γεννάρη καί Δεκέμβρη), καθώς καί τό πεδίο τῶν ἀνωμαλιῶν τῶν πιέσεων αὐτῶν, ἀπό τό μέσο τῆς περιόδου 1900-1972.

Καταλήξαμε στά ἑξῆς συμπεράσματα:

(1) Γιά τίς περιπτώσεις πού ἀνήκουν στό κάτω πεμπτημόριο τῶν παροχῶν, τό Ἰσλανδικό χαμηλό ἐμφανίζεται ἐξαιρετικά ἐνισχυμένο. Ὑψηλός δείκτης κυκλοφορίας ἐπικρατεῖ ἐξάλλου πάνω ἀπό τή ΒΔ Εὐρώπη, ἐνῶ πρός τά ΝΑ, πάνω ἀπό τά Βαλκάνια περίπου, ἐπικρατοῦν θετικές ἀνωμαλίες, μᾶλλον στάσιμος ἀντικυκλώνας.

(2) Γιά τίς περιπτώσεις τοῦ ἄνω πεμπτημορίου τῶν παροχῶν, τό Ἰσλανδικό χαμηλό ἀντίθετα ἐμφανίζεται ἐξασθενημένο ἤ/καί μετατοπισμένο πρός νότο, ὅπως ἐπίσης πρός νότον ἐμφανίζονται μετατοπισμένες οἱ τροχιές τῶν ὑφέσεων.

(3) Τά παραπάνω ἐμφανίζονται σαφῆ καί τοπικά κατά τό Γεννάρη, ἐνῶ κατά τό Δεκέμβρη, στή δεύτερη κυρίως περίπτωση, φαίνεται ὅτι ἐπικράτησαν σέ πολλές περιπτώσεις συστήματα Block.

Γιά τά ἡμερήσια ποσά, ὁρίζεται καταρχάς ἡ ἡμέρα D, στήν ὁποία παρατηρεῖται ἀπότομη καί σημαντική ἄνοδο τῆς παροχῆς τῶν ποταμῶν ὥστε ἡ μέση 24ωρη παροχή νά γίνει $\geq 700 m^3 sec^{-1}$ γιά τόν Ἀχελῶο, ποσό πού ἀντιστοιχεῖ περίπου σέ $\geq 400 m^3 sec^{-1}$ στόν Ἄραχθο, μετά μιά περίπου μέρα. Παρασκευάστηκαν μέσοι χάρτες γιά τήν πίεση ἐπιφανείας, τά 500 mb καί τίς ἰσοπαχεῖς καθώς καί οἱ ἀνωμαλίες τους, πού ἡ στατιστική τους σημαντικότητα δοκιμάστηκε μέ τό κριτήριο t. Αὐτό ἔγινε γιά 9 συνεχεῖς μέρες: τέσσερες μέρες πρίν καί τέσσερες μέρες μετά τή μέρα D.

Καταλήξαμε στά ἐξῆς συμπεράσματα:

(1) Σάν κύριο κέντρο δράσεως γιά τίς μεγάλες παροχές ἐμφανίζεται ἕνα βαθύ καί ἐκτεταμένο βαρομετρικό χαμηλό πού ἐμφανίζεται νά κινεῖται πολύ ἀργά ἀπό τή Δ Εὐρώπη πρός τά Βαλκάνια. Ἡ μεγίστη ἰσχύς τοῦ χαμηλοῦ σημειώνεται κατά τή D περίπου μέρα.

(2) Τό παραπάνω σύστημα προκάλεσε παρατεταμένους καί ἰσχυρούς ΝΔ ἀνέμους καθώς καί γενική ἄνοδο τῶν θερμοκρασιῶν. Ψυχρή μεταφορά παρατηρεῖται στή συνέχεια, μέ διέλευση ψυχροῦ μετώπου κατά τή μέρα D+1.

(3) Ἀνάλυση τῶν μέσων ποσῶν ὑετοῦ ἀπό D-4 μέχρι D+4 γιά διαφόρους σταθμούς τῆς Ἑλλάδας, ἔδειξε ὅτι στήν ὑπόψη περιοχή τά μέγιστα σημειώνονται κατά τή μέρα D, ὅπως ἐξάλλου καί σέ ὅλους τούς πεδινούς σταθμούς τῆς Β. Ἑλλάδας. Τά ποσά ὅμως τοῦ ὑετοῦ στήν ὑπόψη περιοχή ἐμφανίζονται πολλαπλάσια: δύο φορές ὑψηλότερα ἀπό αὐτά τῶν πεδινῶν σταθμῶν τῆς Δ. Ἑλλάδας καί 5-10 φορές ἀπό αὐτά τῶν σταθμῶν Ἀνατολικά τῆς Πίνδου.

Ἀνάλυση τῆς θερμοκρασίας καθύψος στό Ἑλληνικό, ἔδειξε ὅτι κατά τίς μέρες D-1, D καί D+1 ἐπικρατοῦν σημαντικά θερμές ἀέριες μάζες.

Τέλος, συμπεραίνεται ὅτι οἱ ἰσχυρές παροχές τῶν ποταμῶν αὐτῶν, ἐκτός ἑνός ποσοῦ πού ὀφείλεται σέ τήξη τοῦ χιονιοῦ, ὀφείλεται σέ ἰσχυρές βροχοπτώσεις πού ἀρχίζουν πρίν ἀπό τή μέρα D-1 σημειώνονται κατά μεγάλο ποσοστό στό θερμό τομέα καί προκαλοῦνται ἀπό τήν ὀρογραφική ἀνύψωση σέ συνδυασμό μέ δυνητική ἀστάθεια, πού συνήθως ἐπικρατεῖ στή Μεσόγειο.

1. INTRODUCTION

It is well known that the annual precipitation amount on the W part of the Greek peninsula, i.e. W of Pindos mountain range, is at least two times larger than the one E of it. It surpasses 1000 mm, and the same is true for the Ionian sea islands. An exception appears in the Greek islands close to and along the W Turkish coast, where a secondary precipitation maximum appears.

Over the W mainland, precipitation increases considerably with altitude. Early Greek Climatologists attributed this increase indefinitely to the mountain uplift, which is considered by them as the main rain factor (1,2,3).

The synoptic conditions, associated with high 24h precipitation amounts have been qualitatively studied by Papagiannakis and Metaxas (4). They stressed the necessity not only of the suitable wind field but of the importance of the prevailing stability conditions and they noted the existence of warm air masses during these cases.

Detailed meso-scale research, (see e.g. 5,6), described the dynamic factors which cause high precipitation amounts over mountains and converged to the theory that they are primarily caused by potential instability in the warm sector of a depression.

In this work, we intend to study more quantitatively the synoptic conditions that cause high 24 h precipitation amounts, for December and January and the atmospheric circulation anomalies that are associated with high and low monthly precipitation amounts.

As an index for precipitation, the discharges of the Acheloos and Arachthos rivers have been used, as, it has been shown earlier (7,8) that there is a very good correspondence between these amounts, during these months.

Based upon the above finding and on rather poor upper air data in Athens, it is, finally, suggested that the model shown referred earlier in (5,6), is the same, i.e., most of the precipitation is produced by the release of potential instability, in a warm sector of a depression.

2. DATA USED

As stated earlier, as precipitation index, instead of the actual precipitation values in the various existing stations, we used the discharges of the Acheloos river mainly, and the river Arachthos as secondary.

In fact, it is found that on the one hand there is a very high correlation between the discharges of theses two rivers, mainly in the monthly amounts. There is a good series available for discharge observation for the Acheloos river on the other hand, even during the war, 35 years for monthly values up to 1972, when pressure field data are available, kindly provided by MET.O.13 of the Met. Office, G. Britain. For the dayly values, we used a somewhat shorter period and we examined the days with a discharge $\geq 700\,m^3 sec^{-1}$ (mean 24h value) for Acheloos. It is found that this corresponds to about $\geq 400 m^3 sec^{-1}$ for Arachthos.

The precipitation data archive is considered less reliable than the one for the discharge data, due to different periods available for the various stations, to the existing gaps in the series, to the difficulties in selecting the stations and to general difficulties which characterise precipitation measurements, especially in a mountainous terrain.

Two difficulties arise in using the series of the discharge amounts. The first consists in the fact that there is persistence in the series, of a Markof type rather, when the groundwater contribution is important ( ). This is true mainly during the summer months. For the winter, this persistence is hardly significant. The second refers to the melting of the snow, which may take place during the warm days. In fig.
it can be seen that the day of maximum run-off coincides with

the day of maximum precipitation for the stations in W Greece. Therefore, melting of the snow if any, takes place most probably on the same day of maximum precipitation and this does not derange at least the timing of the phenomenon. Furthermore, the time lapse between precipitation and discharge for the Acheloos river is averagely about six hours (4).

3. MONTHLY CIRCULATION WITH HIGH AND LOW PRECIPITATION

The mean monthly circulation, during the extreme monthly precipitation in the considered area, is able to give also good hints for the prevailed synoptic processes. Furthermore, it will be seen that a correspondence may be established between weather in Greece and circulation regimes, that prevailed also in earlier climatic epochs, when no weather information existed in Greek.

Based upon data kindly provided by Δ.Ε.Η., the years with discharge in the upper and lower quintile are noted, seven in each case, in the 1938-1972 period. Mean monthly surface pressure is then computed with its anomaly and the t-value for each grid point, using the MET. 0.13 data file. It may be noted that the t-test of significance for horizontally correlated data, as is pressure, is not the best one. But the significance found in the critical areas was so high that we believe that there is no doubt for this significance in these areas, taking furthermore into account that the main feature appear almost the same in December and January.

In fig. 1, the pressure field and its anomaly for December and January and the upper and lower quintile discharge is shown. We called the latter maxima and minima, correspondingly.

The anomaly field is considered most important. Closed isolines of this field, that enclose areas with anomaly significant at the level 95% or higher, are drawn with continues lines, otherwise dashed. It is furthermore noted that an anomaly maximum or minimum can be approximated by a relative geostrophic vorticity minimum or maximum correspondingly, as the time mean pressure used for the anomaly can be approximated by a space mean one, used for the vorticity. But this should be used away of the areas of strong seasonal systems.

The minimum discharge charts, for December and January, appear quite alike. The most significant feature appears in the Icelandic low, which is very much increased. A positive center over the Balkans and E Europe is less significant and may indicate a blocking anticyclone there. But as anchor system (9) should be considered the Icelandic low. The anticyclone therefore is simply a teleconnection. This means that the physical reasons for this circulation type should be searched in the formation of the former system. In the above circulation type, westerlies appear increased in NW Europe and NE Atlantic. This anomaly pattern does not appear typical case for progressive type of circulation (10), which typically appears in the period 1901-1910 (fig. 2). The westerly current here covers E Europe too.

In the maximum discharge charts, some differences between December and January appear:

In January, the Icelandic low appears decreased and/or displaced southwards. Correspondingly, the Azore's anticyclone appears displaced south and decreased. But even more significant anomaly center is an oblong negative one, along about the 45 deg. lat. This indicates the cyclone tracks and cyclone intensifications area, about the NE Atlantic, i.e. SW of its normal position.

In December, the anomaly field shows the same main patterns, but they are in general less significant. The Icelantic low appears weak and, one may say, the Azore's anticyclone appears extended northwards. Evidently there is blocking warm anticyclone in most cases on its normal position, on the NE Atlantic. Negative anomalies in C Mediterranean may indicate a cut-off low. The statistical significance is not high and one may suggest that this is rather teleconnected to the former center, as in January.

4. THE SYNOPTIC STRUCTURE FOR DAYLY HIGH PRECIPITATION

The first step for this second part of this study was to select , objectively, the cases of high precipitation. We decided that in each case the discharge should have been increased to at least 700 $m^3 sec^{-1}$ (mean 24h amount). The day when this abrupt increase took place is named the D-day. The value of $\geq 700 m^3 sec^{-1}$ is reached in most cases on the D+1 day. It is found that in these cases the discharge of the Arachthos river was $\geq 400 m^3 sec^{-1}$ almost invariably. In the period 1950-1972, 25 such cases were found in December and 18 in January. Taking furthermore into account that each case is found to consist of at least two consecutive days with such a dicharge, we may say that our cases cover about the upper decile of the days.

Using then data of the MET. O. 13 and the UNIVAC 1106 of the Un. of Thessaloniki, we estimated in each grid point, for December and January, the mean pressure, its anomaly from 1950-1972 average along with its t-value to test the anomalies significance, as in par. 3. The same is done for 500mb and thickness and for a nine day period from D-4 to D+4 days. The 54 charts were then manually analysed in that part of the N. Hemisphere, that contains the Atlantic, Europe and Africa N of 25°N, where most of the significant anomalies existed.

The discription of the synoptic structure and evolution will be done at the same time for December and January, but when significant differences appear, these will be especially mentioned.

Four days before the D-day, a highly significant positive anomaly appears in the Atlantic slightly S or SSW of Iceland. The Icelandic low then is displaced SW of its normal position and the surface polar anticyclone extended to S. In fact, it appears that a warm anticyclone is superposed on the strong seasonal systems. This anticyclone persisted for the whole period, strong up to D+2 day. E or ESE of this anticyclone, there is a negative anomaly center, especially significant in January, when its center is about the C Europe.

On D-3 day, in January, another low appears W of the above mentioned anticyclone, which then takes a more oblong shape and becomes even warmer. The main low appears now to have moved on both months to E-NE. The center of the surface low, which is now stronger, lies on the Gulf of Lions, south of the anomaly maximum. Cold air mass is now significant on its W flank.

On D-2 day, the main low becomes stronger with no apparent movement. Greece is covered by even warmer air masses, due to Southerly winds which prevail now stronger. Cold air mass covered now Europe.

On D-1 day, the same evolution is followed, with stronger low and warmer air masses, that now cover Greece. The cold air mass, that invaded the W Mediterranean earlier, now proceeds to E. A cold front should exist over Italy, oriented from SW to NE.

On D-day, the main systems have acquired their maximum force. The front is stronger and closer to Greece, but the warm air mass still covers Greece. This characteristic appears especially intense in January, when the air mass is even warmer over Greece.

On D+1 day, the low moved to E-ENE, as did the thickness anomaly. The cold front now is affecting Greece. Of course its exact position cannot be located. Temperature is still above normal in Greece, but the main warm air mass moved to NE.

On D+2 day, this general movement to NE is continued, with the systems becoming weaker. Greece is still covered by above normal temperatures, which of course now are even lower. The warm air mass is moved further to NE.

On D+3 and D+4 days, the systems became in general weaker. The significance of the anomalies are small. One can say that there is the same trend of evolution. But the low has been split into two; the S part of it, which is moving to E-SE, passed through Greece between D+3 and D+4 days: the north part is moving further away to NE, filling up.

In January, another anticyclone is apparent in N Atlantic on D+4 day and a low over Europe, hardly significant. One is tempted to say that this condition would resemble the one in D-5 day.

In conclusion, from synoptic point of view the intense rainfall is the effect of a well built-up low that moved slowly from W Europe, between D-3 and D+2 days. There was a passage of a secondary low through Greece, but this took place after D+2 day. There was also passage of a front, stronger in January between D+1 and D+2 days. This front was particularly strong N of Greece. By its passage, temperature fell to about normal or slightly above normal levels, after D+2 day.

We finally remark that, as synoptic experience shows, the 24h time interval is too large for an analyst to locate the synoptic systems in detail. One might expect that in actual cases somewhat smaller and faster systems may have acted which can be called satellites systems, without being subsynoptic ones.

5. EPOCH ANALYSIS FOR SOME WEATHER ELEMENTS

The conclusions reached in the previous paragraph will be searched and checked by the study of the evolution of some weather element.

5.1 Precipitation

Mean 24h precipitation amounts for various stations and for the 9-day period, D-4 to D+4, will be examined here.

In the considered area, the average of 5 highland stations in the Acheloos river run-off valey (Templa, Polyneri, Krikelo, Kremasta, Klisto), for the cases whithin their period of functioning (1960-1972) and also in Ioannina and Agrinion, lower stations close to this valey, are at firts examined (fig.). Precipitation started to increase between D-3 and D-2 days. The maximum precipitation intensity is reached on D and D+1 days, for January and December respectively. In fact, if a smooth curve passes through the points, the maximum appears to take place about 12 hours after the D-day. This means 12 hours before maximum discharge of the Acheloos. But the maximum increase of the precipitation amount took place between D-1 and D days. In any case, the exact timing is not tested for significance.

The maximum of the precipitation intensity in every north station showed also on the D day. In Kerkyra, the amount is somewhat less than the one in Ioannina and Agrinion, but in the E Greece stations the amounts are between $\frac{1}{5}$ and $\frac{1}{10}$ of the one in the highland stations.

Finally, in Athens, in the Cyclades Islands and in Crete, the mean precipitation is very low and does not show at all any maximum around the D day. In fact, no precipitation is observed in most cases.

As a conclusion, the synoptic system caused precipitation in the north areas mainly. Precipitation was maximum on the D day, and the amount was much higher in the west. But in highland this was more than two times larger than the one in lower W Greece areas.

5.2 The upper air structure

An indication of the nature and the vertical structure of the air masses involved, before the effect of the mountain range on them, can be given by the study of the superposed epoch analysis of the upper air observations in the only upper air station in the area, in Athens (Hellenikon airport), with some half day time correction. Due to lack of some observations, mainly in the upper levels, the results will be very carefully drawn.

In fig. 6, 7 vertical wind and temperature anomalies epoch analysis is shown, for January and December: A warm front or warm advection appears to have affected the considered area, on about D-2 day. This appears more pronounced in January, when the horizontal temperature gradients are stronger in general. The warm air mass remained over the area up to about D+1 or D+2 days, when cold air mass start invading the area.

The upper resultant wind field analysis is as follows: WNW winds prevail up to D-2 day. Then the wind becomes SW and stronger. Its constancy (not shown) is very high from D-2 to D+2 days mainly in the upper air, where winds above 40 kts and a jet stream at high levels prevail. On the surface, NW winds, with low constancy prevailed on January from D+2 day, indicating a surface low passage in most cases, through or S of Athens.

The above wind field may not be identical with the one over the considered area. The winds must be even stronger there, being closer to the center of the low. The mountains of course should exert a certain influence on them (see e.g. 12), depending mainly on the wind direction and the stability conditions.

Any stability consideration needs also humidity to be taken into account but, in this element, there were more missing observations and, may be, more errors. Also, there may be larger differences between Athens and W Greece. This is why we did not attempt to show it in the diagram. In any case, the dew point was above normal, more than the temperature in most cases, between D-1 and D+1 days. Outside this period, this was below normal, mainly in January.

6. GENERAL CONCLUSIONS AND DISCUSSION

In this study we examined some well difined cases. The associated synoptic condition appeared quite typical: a deep low moved on a W-E track, located north of the considered area. This depression is associated of course with a general upward vertical velocity field, but the observed large horizontal differentiation should be attributed to local factors, and to W to E humidity depletion.

The air masses involved are in most of our cases either cT or mP from NE Atlantic dried up to a certain degree by its run over W Europe. When they run over the Mediterranean, they become gradually humid in their lower level. This causes in general a decrease of their static stability and causes development of potential instability. The latter case appears typically when warm and dry tropical air mass from N Africa is cooled and humidified in its low levels by its passage over the waters of the Mediterranean. This modification corresponds certainly to the creation of potential instability. On the other hand, a cold air mass when runs over the warm Mediterranean water, becomes normally unstable, as it is well known. But, while in the first case instability is released mainly by the mountainrange uptift, in the second the unstable conditions increase the already existing upward vertical velocity field of the depression. We propose therefore the following model:

a. Appreciable precipitation occurs in W mainland when the Southerly warm air current is suitable, in direction and force. Potential instability is one of the most important precipitation factors in this case.

b. Precipitation is continued there when no large change of the wind direction occured and the cold air mass invades from W-NW.

We must finally point out that, in the Mediterranean, precipitation is caused by cold fronts rather than the warm ones (13,14). Appreciable precipitation with warm advection or in the warm sector is restricted to mountainous areas.

R E F E R E N C E S

1. KEFALAS, A., 1928: *"Rainfall distribution in NW Greece* (in Greek), Praktika de l'Academie d'Athènes, 3, 1928, p. 250.

2. MARIOLOPOULOS, H. G., 1935: *"Rainfall systems in Greece"* (in Greek). Agricultural Bul., April 1935.

3. MARIOLOPOULOS, H. G. and CARAPIPERIS, L., 1955: *"Rainfall in Greece"* (in Greek). Athens, 1955.

4. PAPAGIANNAKIS, S., METAXAS, D. A., 1968: *"Meteorological conditions during intense run-off cases of the Acheloos river"* (in Greek) Hell. Nat. Met. Service.

5. BROWNING, K. A., HILL, F. F. and PARDOE, C. W., 1974: *"Structure and mechanism of precipitation and the effect of orograpy in a wintertime warm sector"* Quart. J. R. Met. Soc., 100, 309-330.

6. BADER, M. J. and ROACH, W. T., 1977: *"Orographic rainfall in warm sectors of depressions"* Quart. J. R. Met. Soc., 103, pp. 269-280.

7. METAXAS, D. A., 1973: *"Discharge persistence and forecasting in Acheloos and Arachthos rivers"* (in Greek), Tech. Rep. No 11, Univ. of Ioannina.

8. VASSILIOU, P-C. G. and METAXAS, D. A., 1977: *"Predictive and descriptive models for the monthly average discharge of the Acheloos river"* Bul. Hell. Met. Soc., Vol. 2, 5., pp. 1-15.

9. NAMIAS, J., 1969: *"Seasonal interactions between the North Pasific Ocean and the atmosphere during the 1960"*, s.M.W.R., Vol. 97, pp. 173-192.

10. MURRAY, R. and LEWIS, R. P. W., 1966: *"Some aspects of the synoptic Climatology of the British Isles as measured by simple indices"*. The Met. Mag., Vol. 95, No 1128, pp. 193-203.

11. BLOUTSOS, A. A., 1976: *"The Climate of the upper atmosphere over Athens*, Doctoral thesis, Univ. Thessaloniki.

12. ELLIOT, R.D., and SHAFFER, R.W., 1962: *"The development of qualitative relationship between horographic precipitation and air mass parameters"* J. Ap. Met. I, pp. 218-228.

13. TREWARTHA, G. T., 1966:*"The Eearth's Problem Climates"* Methuen, pp. 223-233.

14. METAXAS, D. A. and REPAPIS, C. C., 1977:*"Large warm advection over Athens:A Climatological and Synoptic study"*. Arch. Met. Geoph. Biokl., Ser.B, 26, pp. 51-61.

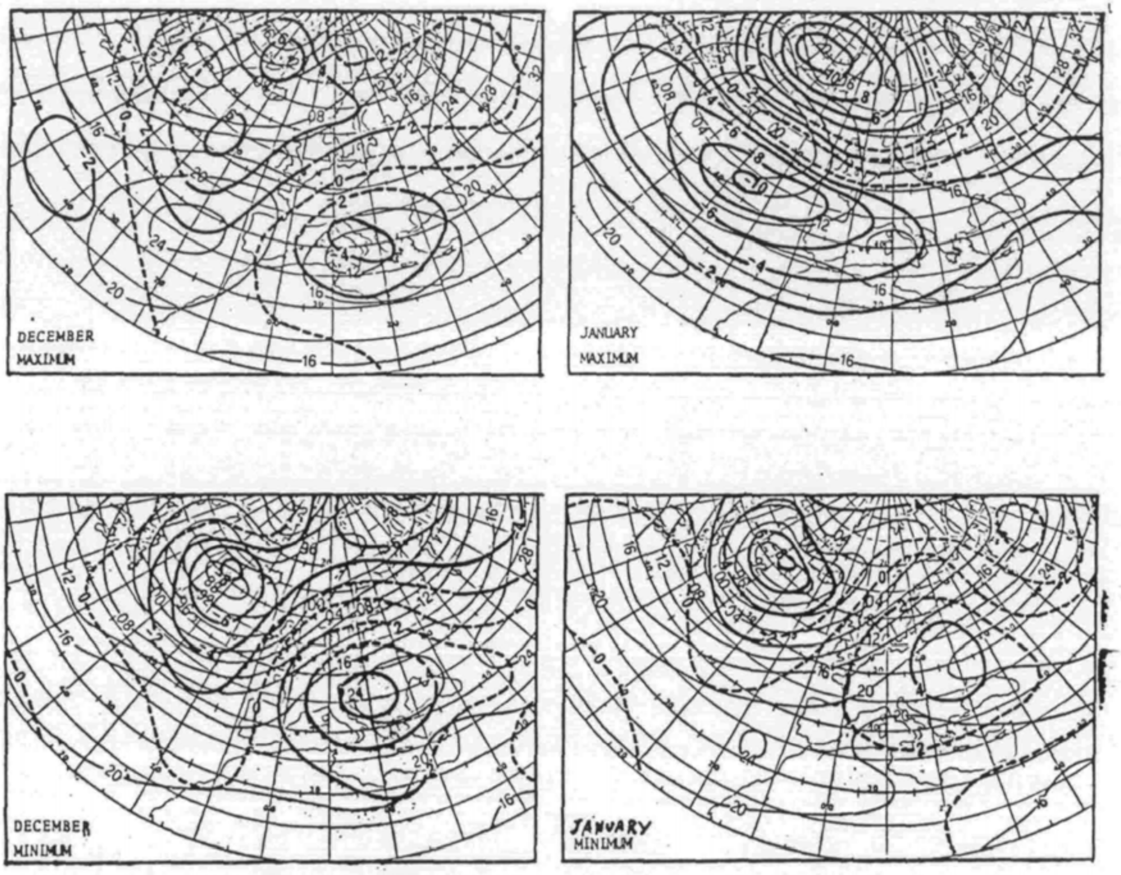


Fig. 1. Mean pressure and anomalies for the upper and lower quintile (maximum and minimum) of the monthly discharges of the Acheloos river. Statistically significant anomaly areas are enclosed by a continues line, otherwise dashed.

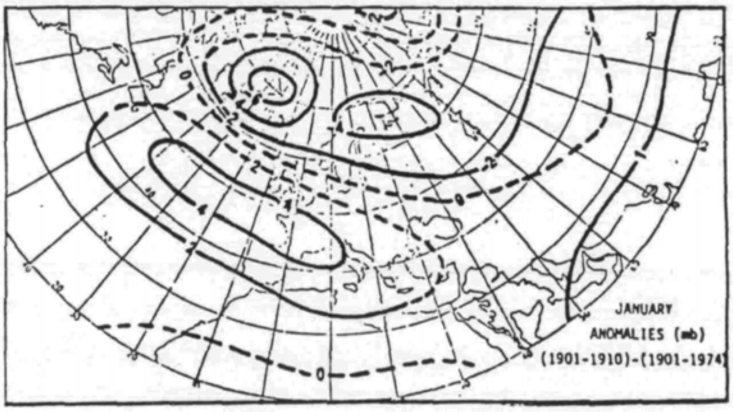


Fig. 2. Anomalies (mb) of the mean 1910-1910 from the mean 1901-1974.

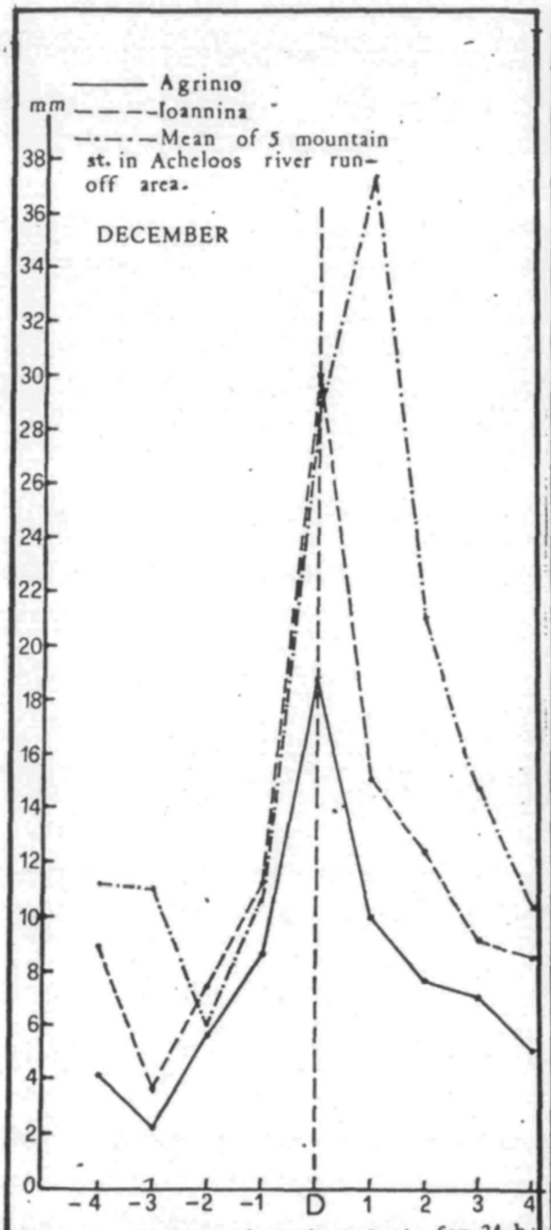


Fig. 5 Superposed epoch analysis for 24 h Precipitation amounts, in December

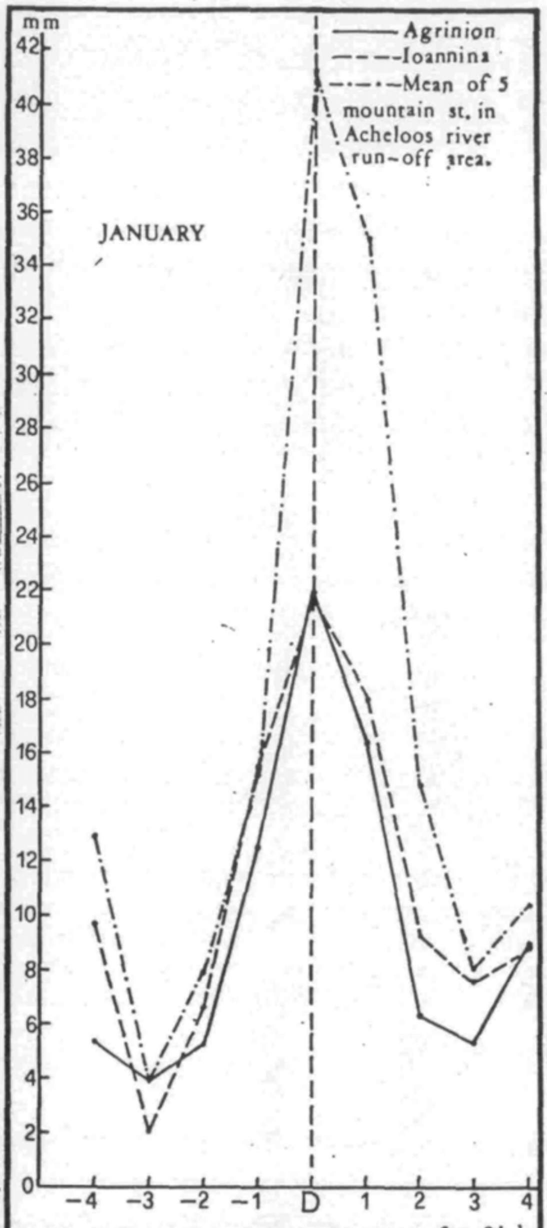


Fig. 6 Superposed epoch analysis for 24 h Precipitation amounts, in January

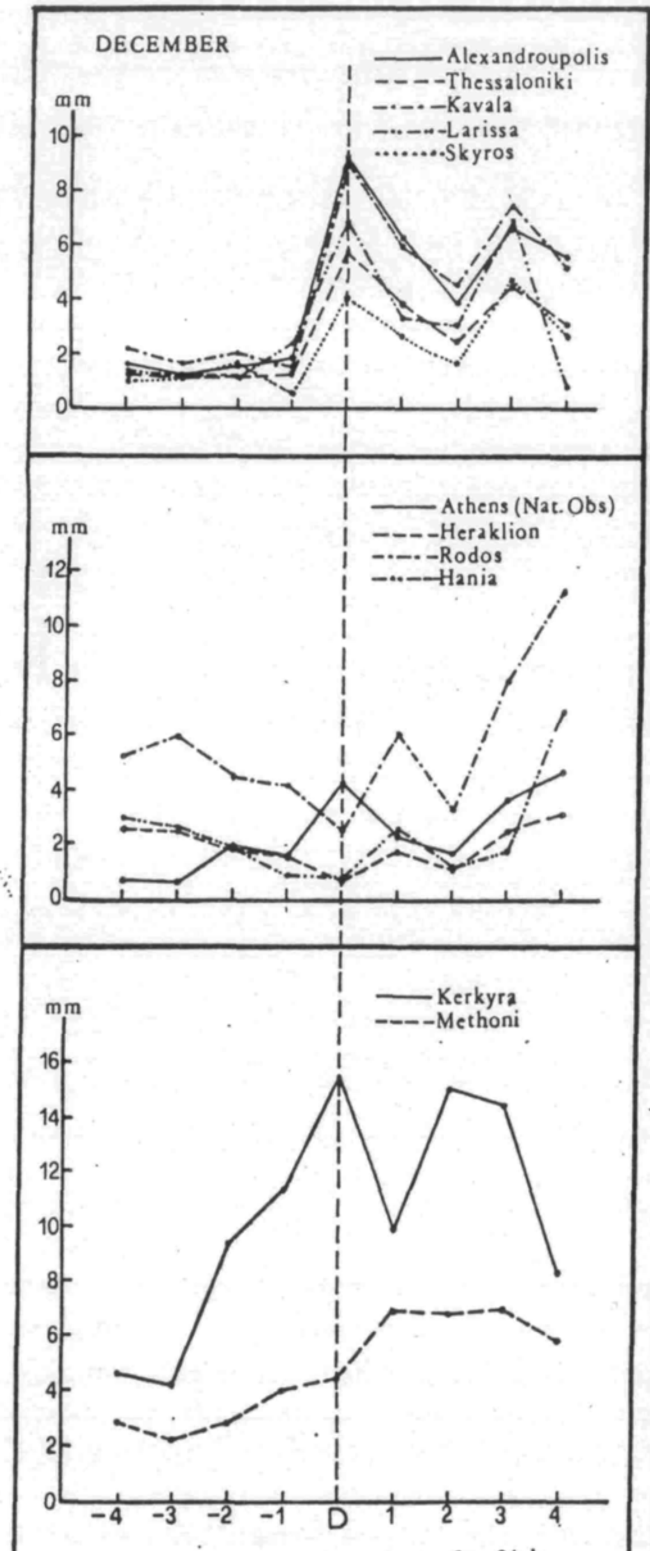


Fig. 7 Superposed epoch analysis for 24 h Precipitation amounts, in December

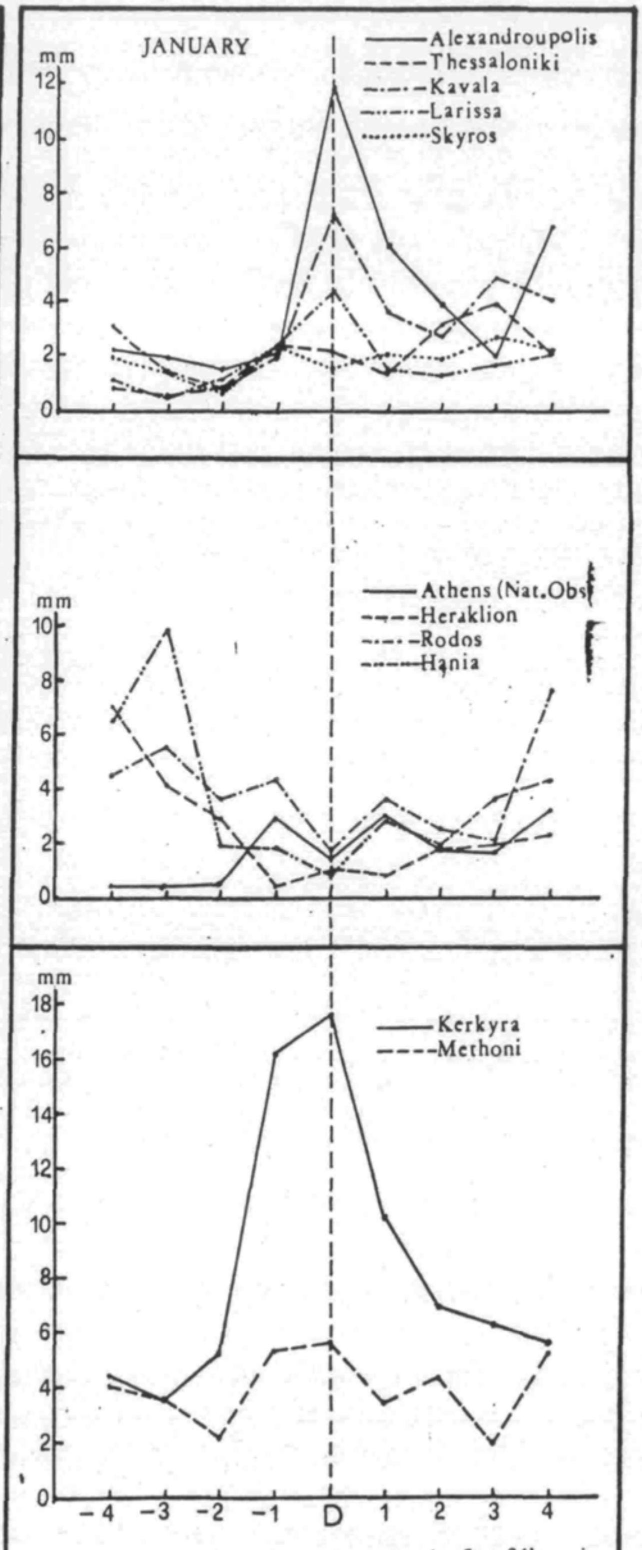
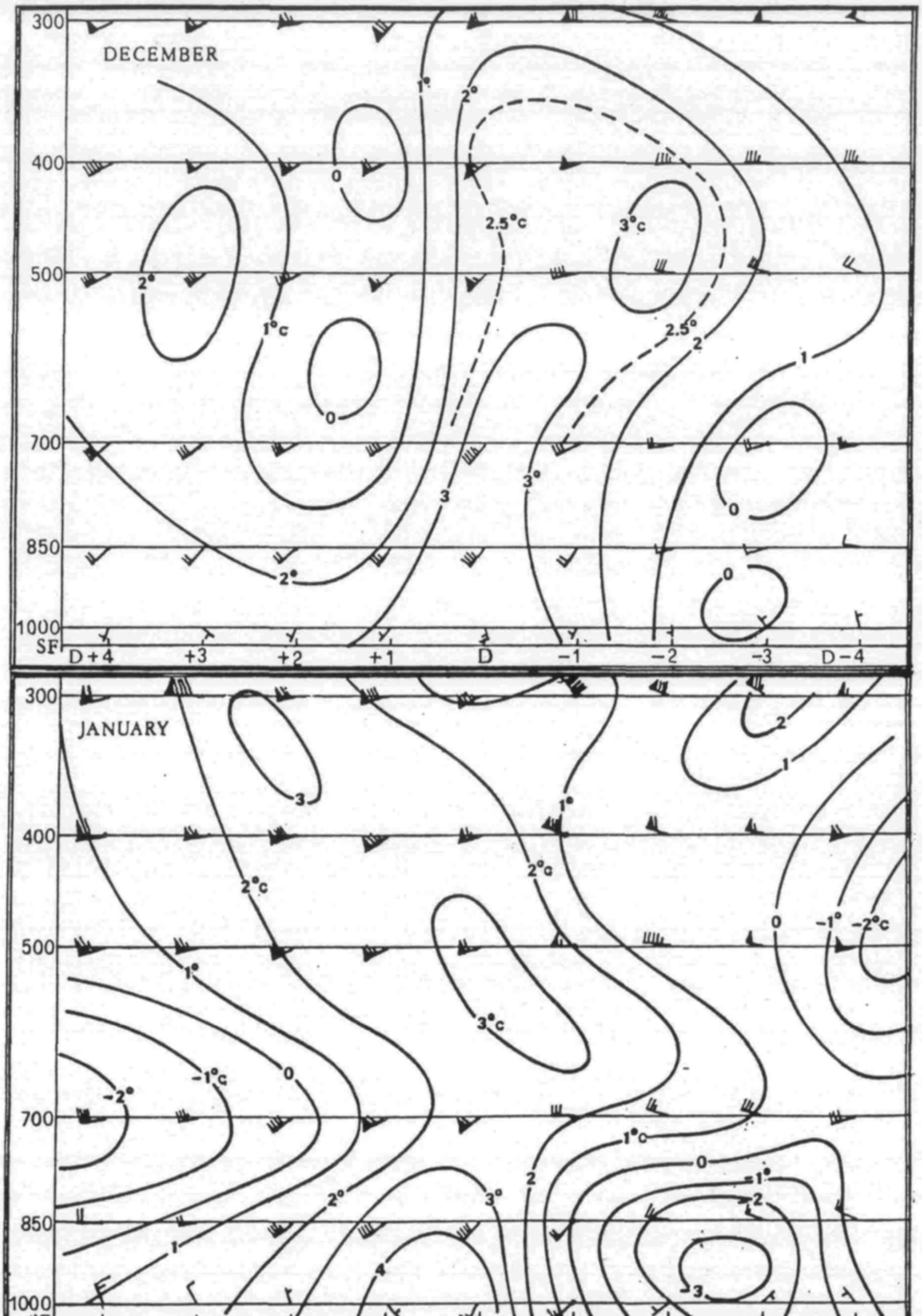


Fig. 8 Superposed epoch analysis for 24h precipitation amounts, in January



Superposed epoch analysis for temperature anomalies and resultant wind with its constancy, in Athens fig. 9.