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DIAGNOSTIC STUDY OF A WINTER MEDITERRANEAN DEPRESSION

By

S. CHR. MICHAELIDIS and V. E. ANGOURIDAKIS

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(Institute of Meteorology, Aristotelian University of Thessaloniki)

Abstract: *This is a case study of a Winter Mediterranean depression in its main stages of development. Cyclogenesis at MSL commenced around 0600 GMT (all times are GMT) of 10th February, 1980, over the Balearie Islands. The depression deepened and moved over Cyprus area, where severe weather conditions have been experienced. The filling of the depression commenced after 0000 GMT of the 14th February.*

The Available Potential Energy and Kinetic Energy regimes are also presented in this study.

The vertical motion field has estimated using the Kinematic method.

The qualitative reference of the relative geostrophic vortieity field is considered to suffice the needs of the present study.

1. INTRODUCTION

The area of the Mediterranean constitutes a region with strong cyclogenetic capability. This characteristic is due to the fact that Mediterranean, being a relatively warm sea, supplies colder air-masses, intruding into the area, with large amounts of sensible and latent heat. This fact contributes towards the cyclogenetic processes as well as to the further development of pre-existing cyclones.

Diabatic changes generally favour the development of depressions in air-masses being transferred over warmer surfaces[3].

The geographical configuration is another factor which enhances the cyclogenetic capability of the Mediterranean.

Cyclones are generally considered as systems where the conversion from available potential energy into kinetic energy takes place. This is determined by the thermal arrangement and the vertical motions within the air-masses in the vicinity of the cyclones. The energy, which is so generated, is partly consumed by the system in order to increase or maintain its circulation, but primarily is exported from the vicinity of the depression. The exported kinetic energy comprises to a large amount the energy which is required for the conservation of the strong westerlies in the atmosphere[2].

2. CYCLOGENESIS OVER THE AREA OF THE BALEARIC ISLANDS

As from 9th February, 1980 a frontal depression, which was originated from the Atlantic ocean, affects Western Europe. The southern part of the cold front moving slowly passes through the Iberian Peninsula over the Mediterranean. This part of the front is relatively non-active.

On the MSL chart of the 1200 GMT of 9th February, 1980 (see fig. 1)* the above mentioned depression is shown having its centre southwest of Ireland. The associated cold front crossing Spain from north to south is shown as well. The strong baroclinic zone which is associated with the frontal system over this area is ohvious from the packing of thickness isopleths over the western Iberian Peninsula.

At the same time, the entire Western and Central Mediterranean is under the influence of a high pressure system, having its centre over the Balkans. The Eastern Mediterranean is under the influence of a low pressure system which is gradually moving eastwards.

As from 0000 GMT of 10th February, 1980, the advection of positive vorticity over the baroclinic zone commences. This is shown in fig. 2a and fig. 2b. The principal maximum of relative geostrophic vorticity over Western Europe is associated with the area of the depression which affects the British Islands, whereas the secondary maximum is advected over the Western Mediterranean (see appendix I).

We refer to relative geostrophic vorticity field qualitatively only. Having this in mind the utilization of the relative geostrophic vor-

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*a. In all 300 mb charts lines are the contours of the 300 mb surface drawn every 60 gpm. Dashed lines, wherever they appear, represent isopleths of relative geostrophic vorticity every $3x10^{-5}$ sec^{-1}.

b. In all 500 mb and thickness charts thick lines are contours of the 500 mb surface and dashed lines are thickness isopleths of the layer 1000 mb-500 mb evrry 60 gpm. These lines, wherever they appear, are isobars at MSL every 4 mb.

c. In all charts the symbols L and H denote low and high respectively. Values of the centre are presented for the major systems. The centre of the system on all MSL charts is indicated by the symbol: ⊕

ticity field, instead of the absolute vorticity field, is considered to suffice the needs of the study in hand.

The advection of positive vorticity implies convergence at low levels and divergence at high levels, within the troposphere.

The result of positive vorticity advection at the 300mb surface over the baroclinic zone and especially over the area of warm advection, is the onset of cyclogenesis at MSL[3]. The first sign of this cyclogenesis is indeed shown on the surface chart of 0600 GMT of the 10th February (see fig. 3).

The advection of positive vorticity over the baroclinic zone continues for the next hours, but no further deepening of the depression is observed, its cyclonic circulation being reinforced rather (see fig. 4a and fig. 4b).

The cyclogenesis occured in the area of the Balearic Islands and then, steered by the thermal wind[7] the depression moved initially eastwards and then to the south (see fig. 5a).

3. CYCLONIC CIRCULATION IN THE UPPER LEVELS OF THE TROPOSPHERE

From the time of the onset of the closed cyclonic circulation at MSL, this closed circulation is confined only to the lowest layers of the atmosphere till the 1200 GMT of the 13th February (see fig. 7a and fig. 7b).

As from 1200 GMT of 11th February, however, there appears advection of cold air of polar origin from north to south and through the entire troposphere. The advection is accomplished by the northerly airflow to the west of the diffluent through (see fig. 6). On the other hand warm air advection is taking place ahead of the through from south to north.

The process of the above mentioned meridional mass advections, together with the vertical stretching, which the air-masses undergo in the region of the vertical motions of the atmosphere, have as a result the further increase of the cyclonic curvature in the areas of Crete and Romania, in the medium and high levels of the troposphere. This is ascribed to the tendency of the air-masses to conserve their absolute vorticity in the course of their meridional displacements, and in particular at the level of non-divergence[3].

Finally the continuance of this process completes the closed cyclonic circulation at all levels of the troposphere, as it can be seen from the charts of 0000 GMT of 14th February (see fig. 8a and fig. 8b). This takes place for the first time since the cyclogenesis at MSL.

4. DEEPENING OF THE DEPRESSION

It has been observed that there is a tendency for cyclogenesis or for further deepening or a pre-existing depression, when cold air-masses are brought over the warmer waters of the Mediterranean. The contribution of the sensible and latent heat to the cyclogenetic processes or to the deepening of a pre-existing depression is of considerable importance.

In the early stages of the development and in the stages of the further deepening of the depression, the transfer of sensible heat from the sea surface to the directly overlain colder air-mass, contributes to the increase of the available potential energy in the area of the depression. In a winter Mediterranean depression the mean generation of available potential energy in the lower layers of the troposphere was estimated as 0.5 Wm^{-2} (8).

The deepening of the depression commenced as from 0000 GMT of 11th February. Its further eastward movement is again ruled by the thermal steering effect.

As it can be seen from fig. 5a, since the re-establishment of the depression over the sea surface, the depression remains in the relatively warmer part of the Mediterranean. This fact contributes to its further development.

The maximum deepening of the depression took place around 0000 GMT of the 11th February. At this time its centre was found between Cyprus and Crete (see fig. 5b).

The tangent of the angle of tilt (from the vertical) of the axis of the low from MSL to the 300mb surface is represented in Table I. The axis tilts to tbe northwest and towards the colder air. The tilt is greatest before the time of maximum deepening of the depression at MSL. This is necessary for the further development of the surface depression because with this arrangement the depression is found beneath the area where divergence is present on the upper levels of the troposphere. The tilt takes its minimum around the time of maximum deepening of the depression and the mechanism mentioned above ceases, henceforth, its contribution to the further deepening of the system and generally to its development.

TABLE I

	0000 GMT	1200 GMT	0000 GMT
TIME	13 Feb.	13 Feb.	14 Feb.
TAN. OF. ANGLE OF TILT	87	56	15

The phase difference between the pattern of the MSL isobares and the thickness pattern (which is equivalent to the mean isotherm pattern) of the 1000mb - 500 mb layer is obvious throughout the development of the system (see fig. 7b and fig. 8b). The simultaneous cold-air advection behind and warm-air advection ahead of the trough is accomplished through this arrangement.

The formation of a cold pool and its advection over the area of Cyprus (see fig. 9) is directly associated with the increase of the instability of the air-mass over the area.

The depression affected, mainly, the weather of the Eastern Mediterranean with strong surface winds, extensive rainfall and thunderstorms. The severity of the weather situation was also due to widespread tornado activity which, in some cases, caused damage in property.

5. THE LAST STAGE OF THE DEPRESSION

Fig. 5b shows the pressure tendency at the centre of the depression at MSL. The maximum deepening occured, as it has been mentioned in the previous paragraph, around 0000 GMT of 14th February. The filling of the depression was set up after that time. The weakening of the depression proceeds at a higher rate than its deepening.

From 1800 GMT of 14th February a separation of the cyclonic circulation into two weaker cyclonic circulations, which follow different tracks, is being observed. One of these lows moves eastwards and the other northwards (see fig. 5a). The phenomenon of the separation of a single cyclonic circulation into two (rarely into more than two) has been observed in association with other depressions being in their last stages of filling and particularly over the area of Cyprus. The separation of the cyclonic circulation at low levels may have been induced mechanically, as Cyprus constitutes a geographical barrier to the course of the depression. Nevertheless there is a connection with a similar separation observed in the upper levels of the atmosphere. This is shown in fig. 9.

The formation of these cold lows to the south of the strong westerlies of the atmosphere comprises part of the procedure for the meridional exchange or airmasses[2].

As soon as the subsidence of the cold air has started, the low in the area of Cyprus waekens-both as a circulation system and as a thermal pattern-evidently absorbed by the environment. The other low pressure system over Asia Minor is finally merged with the stronger cyclonic system approaching from the NW (fig. 10). The latter is the system mentioned is paragraph 3, as been generated in the medium amd high troposphere over Romania.

6. THE VERTICAL MOTION FIELD

In fig. 11 the vertical motion field of the atmosphere in a cross-section along the curve BB′ of fig. 7a, is presented. Curve BB′ coincides with an arc of the 38^0 N parallel. The temperature distribution (isotherms drawn every 10^0 C) is also presented in this cross-section.

Vertical motions in the atmosphere may equivalently presented by the pressure tendency $\omega = \frac{dp}{dt}$ and are therefore expressed in mb sec^{-1}. Calculations of ω have been carried out by the intergration of the continuity equation,

$$\omega_{pt} = \omega_{pb} + \int_{p_t}^{p_b} \vec{\nabla} \cdot \vec{V} \, dp$$

where ω_{pt} , ω_{pb} are the values of ω at the isobaric surfaces p_t and p_b respectively ($p_b > p_t$).

This is the so-called kinematic method for the estimation of ω. The boundary condition $\omega=0$ at the earth's surface is incorporated.

In this cross-section two maximum and two minimum of ω can be recognized. Positive values reflect descending motions of the airmasses, whereas negative values reflect ascending motions of the air masses.

Comparing the values of ω with the isotherms in the same cross-section, one generally notes that the positive values of ω occur in areas with lower temperatures, whereas negative values in areas with higher temperatures.

Thus, on the average, warmer air-masses are ascending and colder air-masses are descending, at the same level. From this relationship one may come to the conclusion that the mechanism for the conversion of available potential energy of the atmosphere into kinetic energy of the atmosphere has been established.

7. AVAILABLE POTENTIAL ENERGY IN THE AREA OF THE DEPRESSION

Available potential energy (APE) is the fraction of the total potential energy of the atmosphere which can be converted into kinetic energy of the atmosphere.

An approximate expression for the available potential energy over an area A is given[1]

$$APE = \frac{1}{2} \int_p \int_A \frac{1}{\overline{T}\,(\gamma_d - \overline{\gamma})} T'^2 \, \delta A \, \delta p$$

where $\overline{T}$ is the mean temperature on an isobaric surface* p, T′ the departure from this mean, γ_d the dry adiabatic lapse-rate and $\overline{\gamma}$ the mean value of the vertical lapse-rate.

The integration is made over an area with dimensions 1260 km x 1260 km at 35°N, the centre of which is moving along with the centre of the depression at MSL and in the layer p_b=500 mb and p_t=300 mb. In this layer a mean temperature $\underline{T}$ is considered (see appendix III).

The mean available potential energy per unit area can be written

$$\overline{APE} = \frac{1}{2} \frac{1}{A} \frac{1}{\gamma_d - \overline{\gamma}} \frac{1}{\underline{\overline{T}}} (p_b - p_t) \sum_i (\underline{T}')_i^2 \, \delta A_i$$

where $\underline{T}'_i$ is the departure from the mean temperature $\underline{T}'$ in the subarea δA_i of the grid.

Fig. 12 represents the $\overline{APE}$ versus time in the area of the depression. Starting with a maximum value at 1200 GMT of 13th February, APE decreases and obtains its mimimum around 0000 GMT of 14th February. The latter is considered as time of the maximum deepening

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* The dash over a function (¯) represents the mean value of this function over a horizontal surface (isobaric).
The dash beneath af unctuon (_) represents the mean valne of the function within the layer $p_b - p_t$.

of the depression. The decrease of APE implies conversion of APE into kinetic energy. In the previous paragraph it has been stressed that the conditions favour such a conversion within the atmosphere.

An increase of the APE is furtheron observed. This increase is due to the reverse conversion, that is, from kiuetic energy into available potential energy. This increase of APE is accomplished at a lower rate[5].

8. STUDY OF THE KINETIC ENERGY FIELD

The total amount of kinetic energy of the mass of the atmosphere over an area A, which is bounded by the isobaric surfaces p_b and p_t ($p_t<p_b$) and which is due to the horizontal wind component only, can be written as[4]

$$K = \int_A \int_p \frac{1}{2g} V^2 \, \delta p \delta A$$

where V denotes the wind speed over the isobaric surface p and g is the acceleration of gravity.

From the above integral the mean kinetic energy of the layer p_b-p_t of the atmosphere and over the area A (or otherwise the mean kinetic energy per unit area) is

$$\overline{K} = \frac{1}{A} \int_A \int_{p_t}^{p_b} \frac{1}{2g} V^2 \delta p \delta A$$

In the present study the calculation of the kinetic energy per unit area has been carried out for the layers SURFACE-700 mb, 700 mb-500 mb and 500 mb-200 mb. For the three fixed areas, shown in fig. 8a and for each of the afore mentioned layers, a mean wind speed has been taken into account (see appendix II).

The above integral is approximated with the aid of a calculation grid for each of the areas A, B and C. The grid is composed of 16 sub-layers each having dimensions 310 kmx310 km at 35^0 N. For constant g the integral aquires the numerical form

$$\overline{K} = \frac{1}{2Ag} (p_b - p_t) \sum_{i=1}^{16} \underline{V}_i^2 \, \delta A_i$$

where $\underline{V}_i$ is the value of $\underline{V}$ (for the layer $p_t - p_b$) over the sub - area δA_i of the grid.

The last relationship yields the following approximate expressions:

Kinetic energy per unit area for the layer SURFEACE-700 mb $= 94 \sum_{i=1}^{16} \underline{V}_i^2$

Kinetic energy per unit area for the Layer 700 mb - 500 mb $= 63 \sum_{i=1}^{16} \underline{V}_i^2$

Kinetic energy per unit area for the layer 500 mb - 200 mb $= 94 \sum_{i=1}^{16} \underline{V}_i^2$

It is not possible to have accurate results because of the lack of a sufficiently dense upper-air network.

The kinetic energy per unit area for each of the areas A, B and C and for the consecutive layers SURFACE-700 mb, 700 mb-500 mb and 500 mb-200 mb is depicted in fig. 13.

Area B may be considered as the area enclosing the depression for the most of the time, despite the fact that it is not feasible to determine fixed boundaries in such a case. Area A is situated behind the depression, whereas area C is situated ahead of the depression. We can not ignore the possibility of making an error in the arithmetic calculations when only real winds are been involved. Nevertheless, it is considered tbat the general characteristics of the change of kinetic energy are maintained.

a. In general, area A remains at low energy levels. A quasi-stationary minimum of kinetic energy has been observed over Asia Minor.

b. In areas B and C the maximum occurs after the time of the maximum deepening of the depression.

c. Large amounts of energy are initially present in the medium and high levels over the area C. On the contrary small amounts of energy are present in the lower layers. This ascribed to the existence of the sub-tropical jet-stream in the upper levels of the troposphere.

d. Generally area C has a higher rate of kinetic energy increase in all layers. After 1200 GMT of 14th February we note a decrease of kinetic energy in the lowest layer of SURFACE - 700 mb. This decrease is attributed to the action of friction forces. This is more pronounced in the lowermost layer, where friction between the air and the earth's surface results, directly, in a decrease of the wind speed. In the medium and high levels a further increase of kinetic energy is taking place, even after that time.

e. In the lowest layer SURFACE - 700 mb the kinetic energy has a marked tendency to be restored at low levels soon after it reaches its maximum. This fact is due to the action of friction forces between the atmospheric air and the earth's surface.

f. Area A is associated with the strong current to the west of the upper trough. This strong current is considered to be a branch of the polar-front jet-stream. Comparing areas A and C (C is under the influence of the sub-tripocal jet-stream) we can see the different kinetic energy regimes these two areas. Especially after 0000 GMT of 14th February - when the maximum winds have been transfered to the east of the npper trough-one observes a decrease of kinetic energy in area A and a further increase in area C, in the medium and high levels of the troposphere (see also par. 9).

9. SOME NOTES ON THE BEHAVIOR OF THE JET - STREAM OF THE UPPER TROPOSPHERE

The generation of kinetic energy in area of the depression does not necessarily imply an increase of the kinetic energy within this area; kinetic energy is usually exported from this area.

The cross-sections of fig. 14, constructed along line AA′, shown in fig. 7a, present two isotach analyses-isotachs being drawn every 10kt. The first isotach analysis (continuous lines) is for 0000 GMT of 13th February, while the second (dashed lines) is for 0000 GMT of 15th Fervuary. Comparing these two cross-sections, we note the following.

a. The single maximum at 0000 GMT of 13 February (see in the right hand part of the figure) is ascribed to the presence of the subtropical jet-stream over the area of Persian Gulf. This has also been mentioned in note c., of the previous paragraph.

b. The maximum winds of the polar-front jet-stream have been transfered from west to east of the upper trough within 48 hours. When this transfer was completed, the depression had already filled. The polar-front jet-stream is seen in the middle of fig. 14.

c. Along with the increase in the wind speed in the area of the polar-front jet-stream, one can observe a similar increase in the area of the sub-tropical jet-stream.

d. The core of the sub-tropical jet-stream has suffered a small displacement from north to south and, at the same time, towards the lower layers of the atmosphere.

It is not feasible to determine with certainty, the area which received the kinetic energy which had been generated within the area of the depression. However, the rainforcement of the wind field in the area of the jet-stream (and consequently the increase of the kinetic energy of the atmosphere in that area) may, in part, be due to the import of kinetic energy in that area, exported from the area of the depression.

10. CONCLUSIONS

a. The depression that has been studied, constitutes a typical example of cyclogenesis in the Western Mediterranean, by the process of advecting the positive vorticity of the higher layers of the troposphere, over a baroclinic zone of the medium and lower layers.

b. This synoptic disturbance is considered as a disturbance of the polar-front. With low-index circulation there is a displacement of the activity of the depressions towards the Mediterranean.

c. The depression deepens as long as the mechanism of simultaneous divergence in the upper levels and convergence in the lower levels of the troposphere is present. The filling of the depression commences as soon as this mechanism is destructed.

d. At least 12 houts before the time of maximum deepening of the depression, the necessary process for the conversion of available potential energy - in the area of the low - into kinetic energy, is inherent in the atmosphere.

e. The depression acted as an energy conversion system. From this point of view this depression is considered as a «source» of kinetic energy; kinetic energy was mainly exported from the area of the depression.

APPENDICES

I. For the calculation of the negative geostrophic vorticity of the 300 mb isobaric surface[6]

$$J = \frac{g\nabla^2 z}{f}$$

(where $f = 2\Omega \sin\varphi$, Ω the angular velocity of the earth, is the Coriolis parameter at latitude φ, g the acceleration of gravity and $\nabla^2 z$ is the Laplacian of the 300 mh contour field) a grid was utilized. This grid comprises of 117 squares, each of them having dimensions 439 km X 439 km at 35^0 N. The acceleration of gravity was taken as a constant, $g = 9.80$ m sec^{-2}.

II. The mean wind speed in the layer $p_b - p_t$ was worked out with the aid of the mean value theorem

$$\underline{V} = \frac{1}{p_b - p_t} \int_{p_t}^{p_b} V dp$$

or in its numerical form

$$\underline{V} = \frac{1}{p_b - p_t} \sum_{i=1}^{K} V_i \, \delta p_i$$

where k is the number of sub-layers and V_i is the wind speed in the sub - layer δp_1.

III. The mean temperature $\underline{T}$ of the layer 500 mb - 300 mb was taken from the thermodynamic diagrams and in such a way that energy of the layer tremains unchanged.

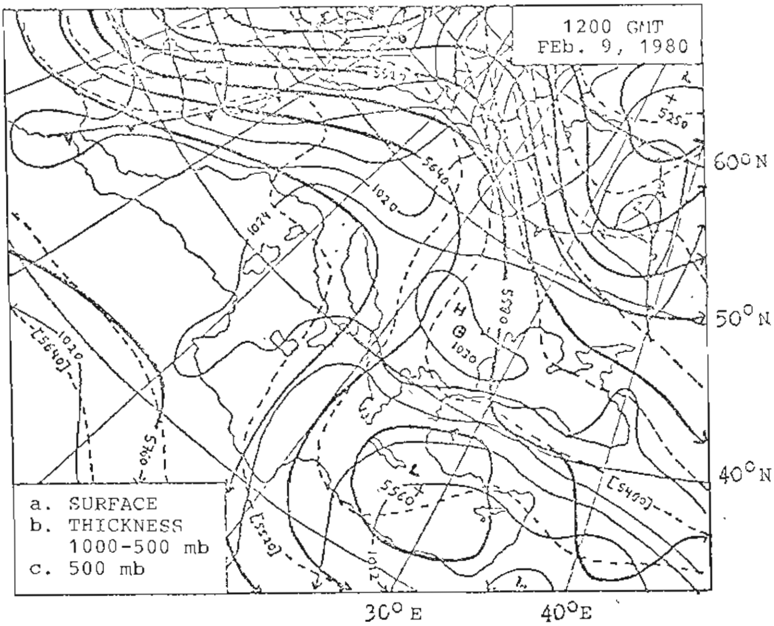
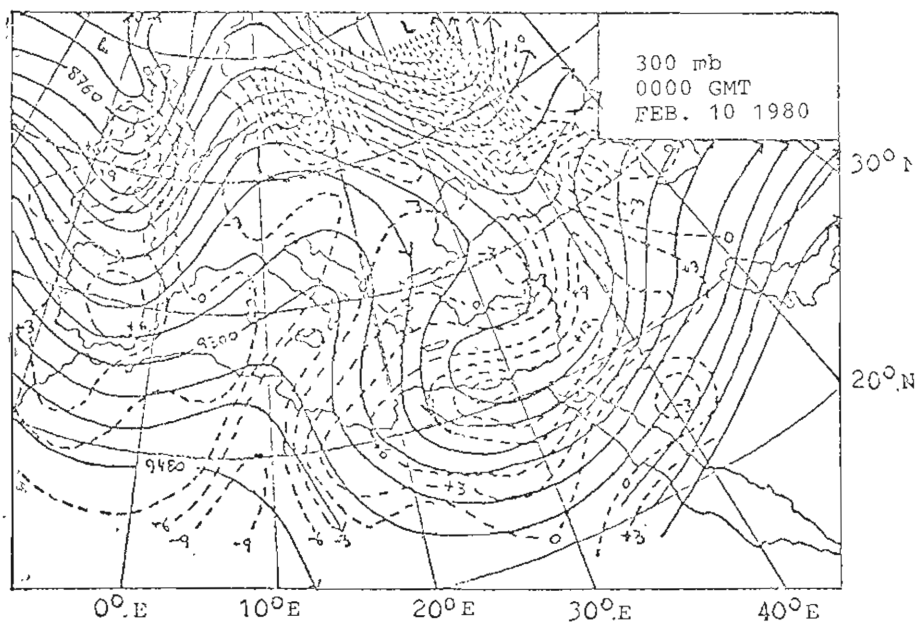

1200 GMT
FEb. 9, 1980
a. SURFACE
b. THICKNESS
1000-500 mb
c. 500 mb
60° N
50° N
40° N
30° E
40°E

Fig. 1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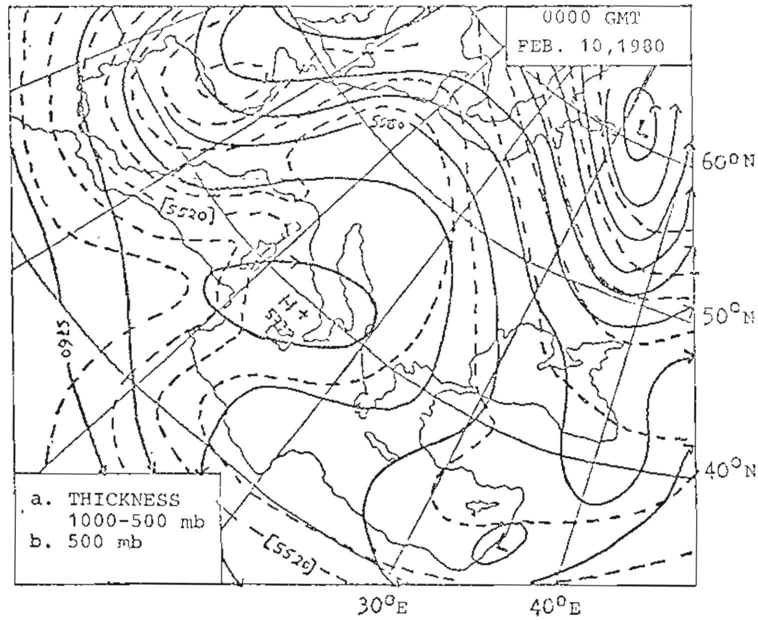
0°.E
10°E
20°E
30°.E
40°E

Fig. 2a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FEB. 10,1980
60°N
50°N
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40°E
a. THICKNESS
1000-500 mb
b. 500 mb
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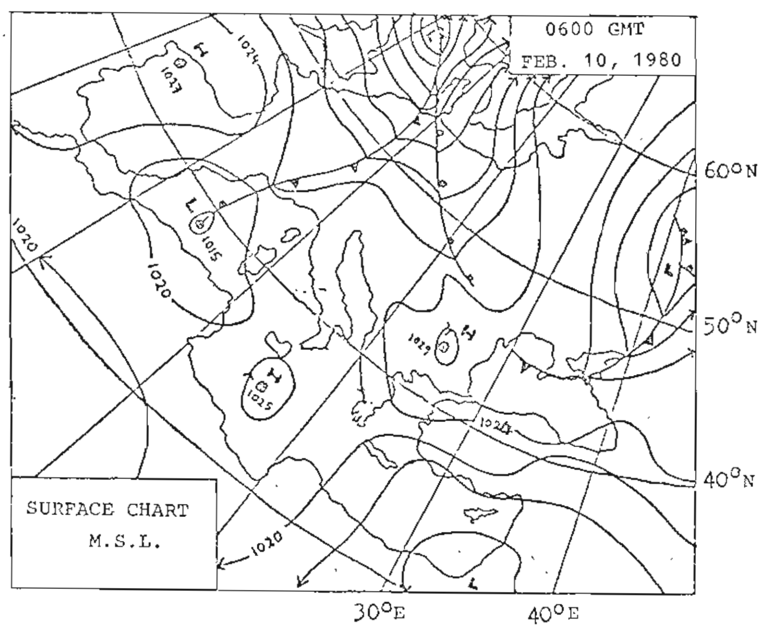
5580
5760
H
L

Fig. 2b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SURFACE CHART
M.S.L.
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40°E
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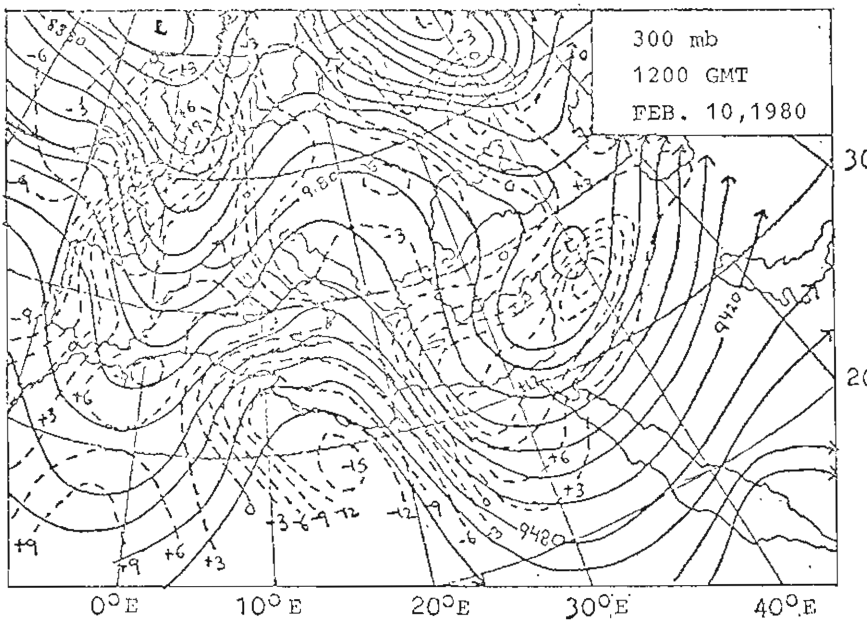
1020
1015
1025
H
L

Fig. 3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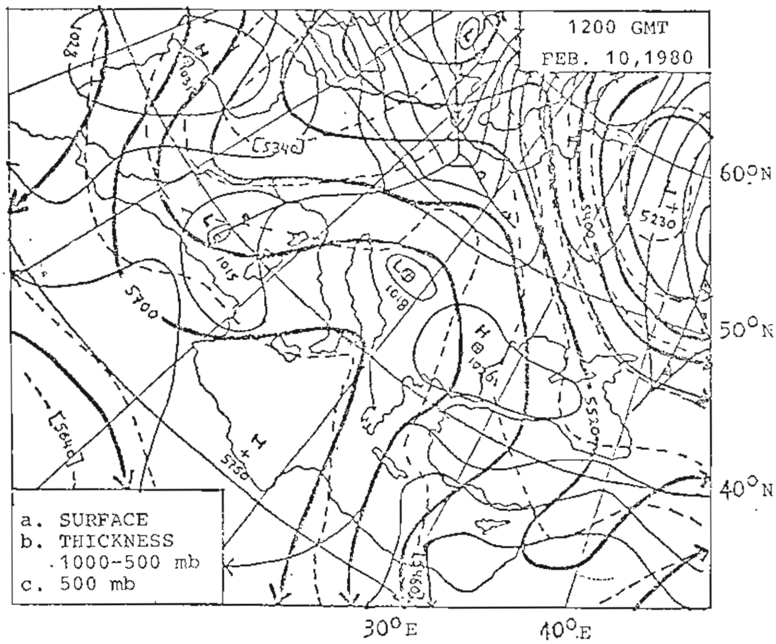
20°E
30°E
40°E

Fig. 4a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FEB. 10,1980
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50°N
40°N
30°E
40°E
a. SURFACE
b. THICKNESS
1000-500 mb
c. 500 mb

Fig. 4b

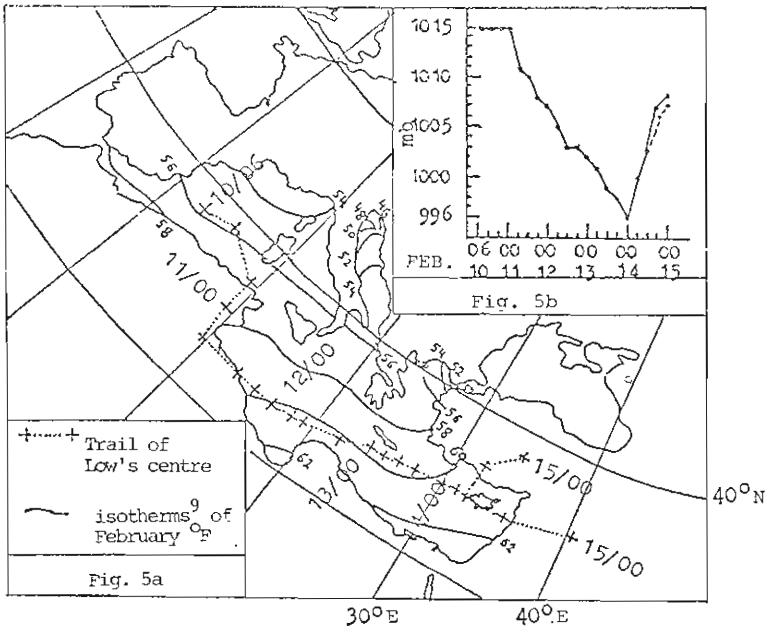


Fig. 5a and 5b

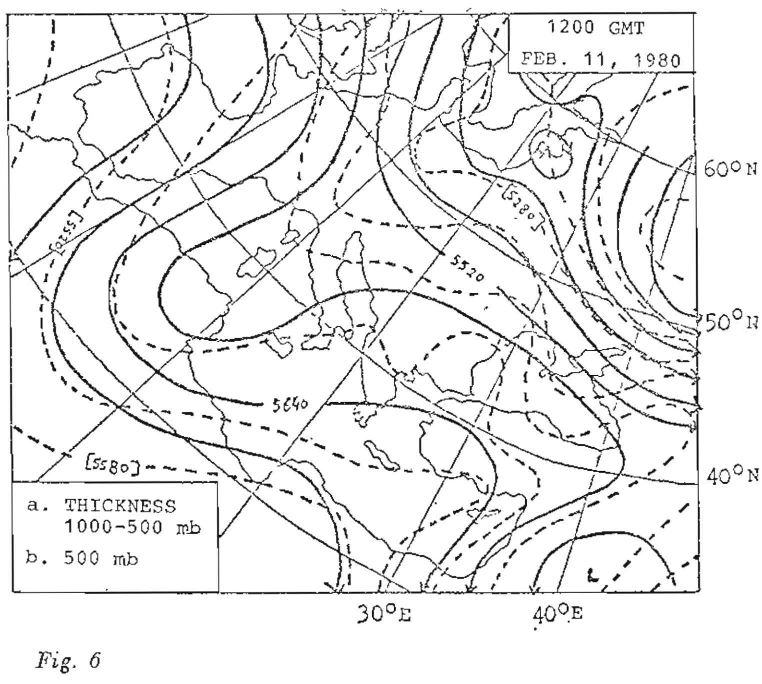
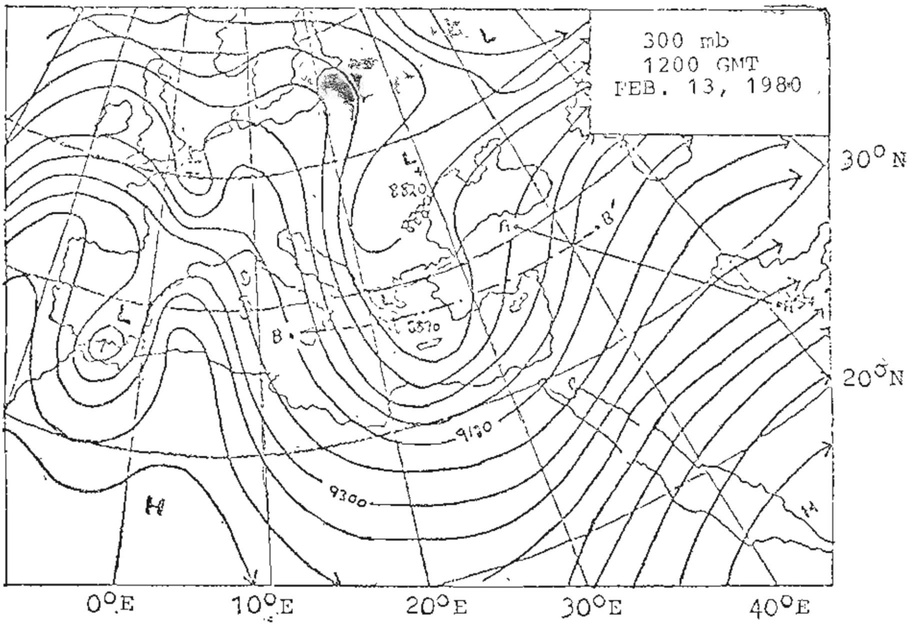


Fig. 6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1200 GMT
FEB. 13, 1980
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8820
H
L

Fig. 7a

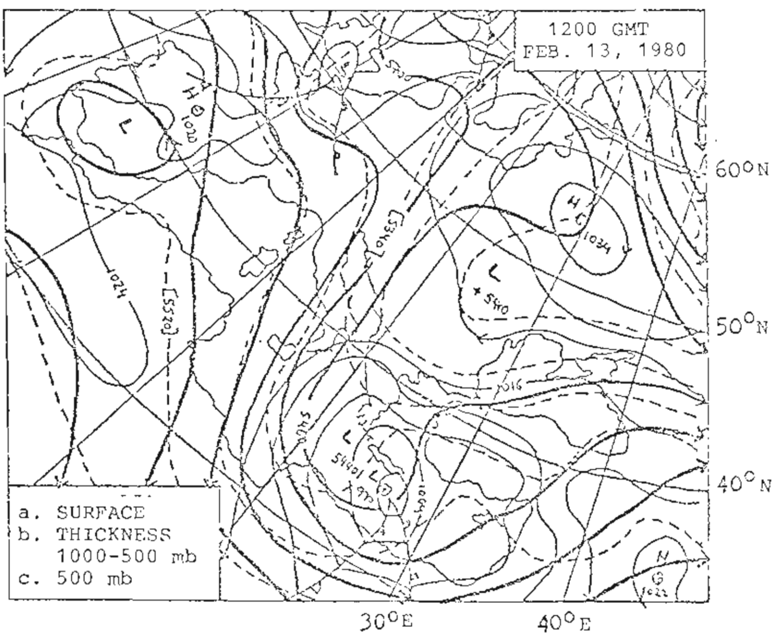
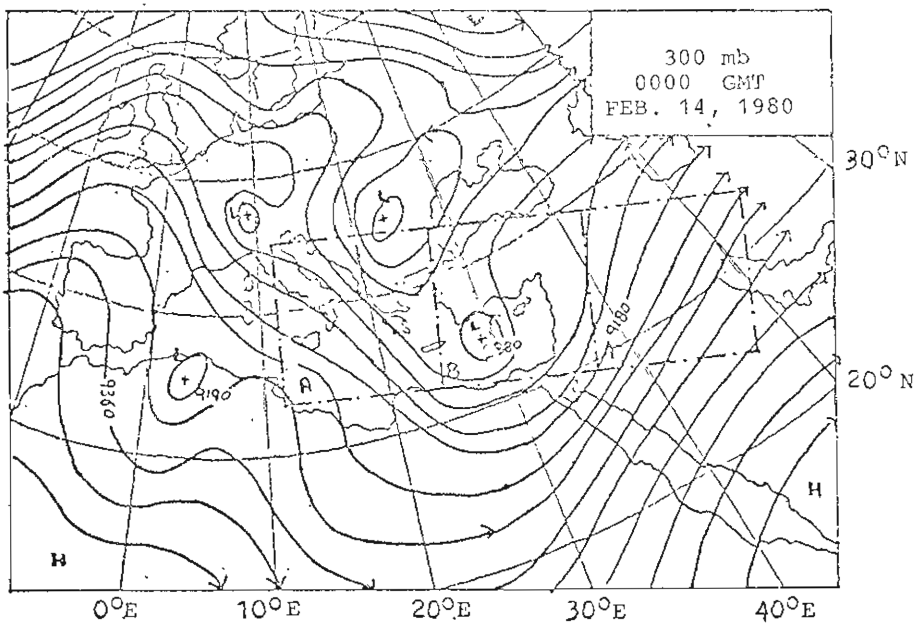

1200 GMT
FEB. 13, 1980
60° N
50° N
40° N
30° E
40° E
a. SURFACE
b. THICKNESS
1000-500 mb
c. 500 mb
1034
1024
1016
[5520]
[5340]
5440
L
H

Fig. 7b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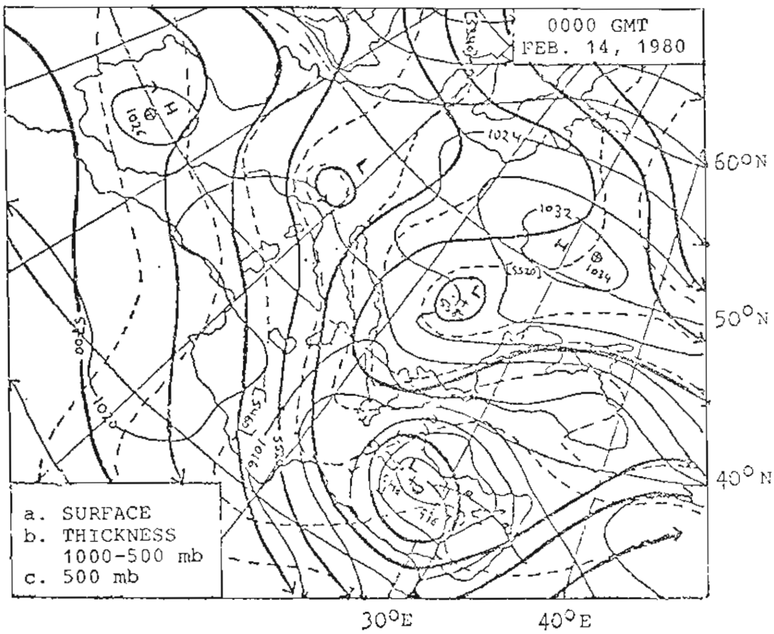
20° N
0°E
10°E
20°E
30°E
40°E

Fig. 8a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40°E
a. SURFACE
b. THICKNESS
1000-500 mb
c. 500 mb

Fig. 8b

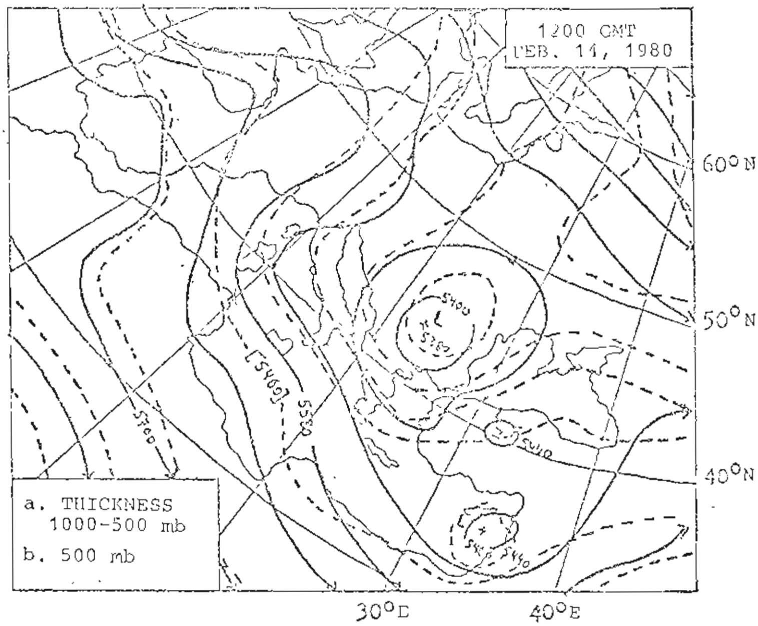
1200 GMT
FEB. 14, 1980
60°N
50°N
40°N
a. THICKNESS
1000-500 mb
b. 500 mb
30°E
40°E

Fig. 9

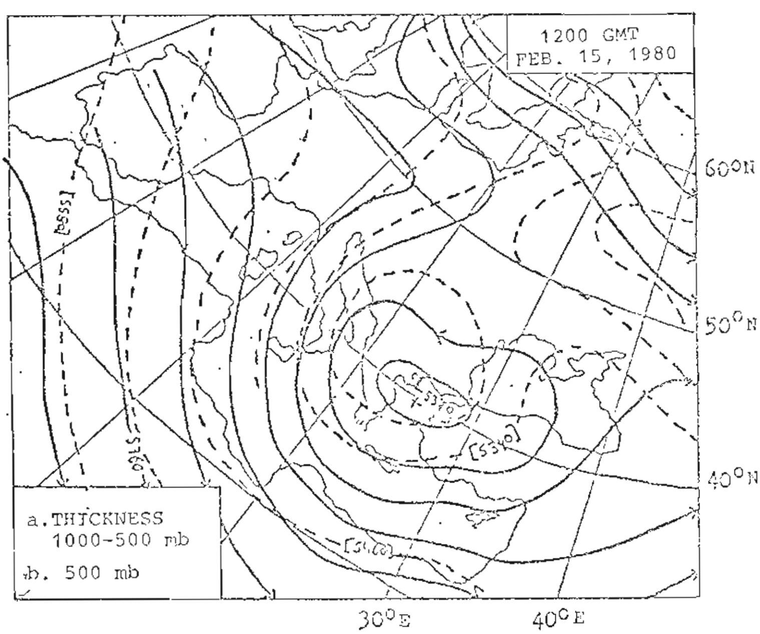
1200 GMT
FEB. 15, 1980
60°N
50°N
40°N
a. THICKNESS
1000-500 mb
b. 500 mb
30°E
40°E

Fig. 10

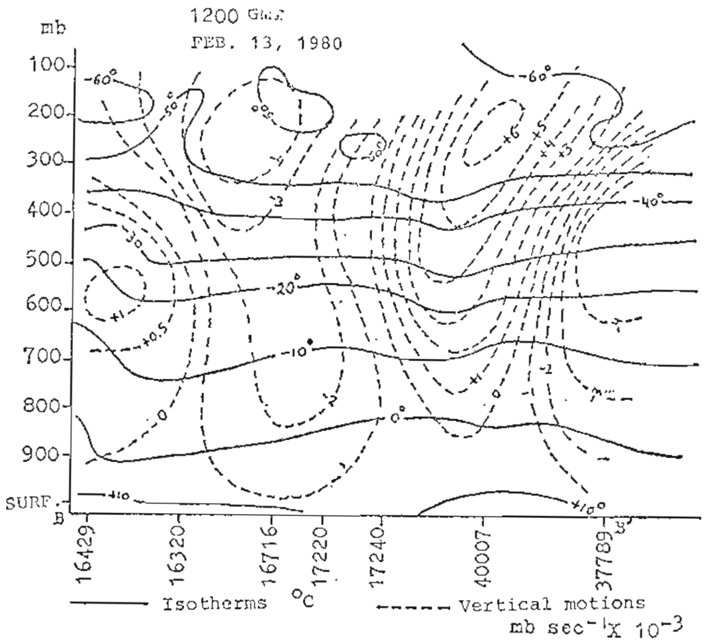
1200 GMT
FEB. 13, 1980
mb
100
200
300
400
500
600
700
800
900
SURF.
16429
16320
16716
17220
17240
40007
37789
Isotherms °C
Vertical motions
mb sec⁻¹ X 10⁻³

Fig. 11

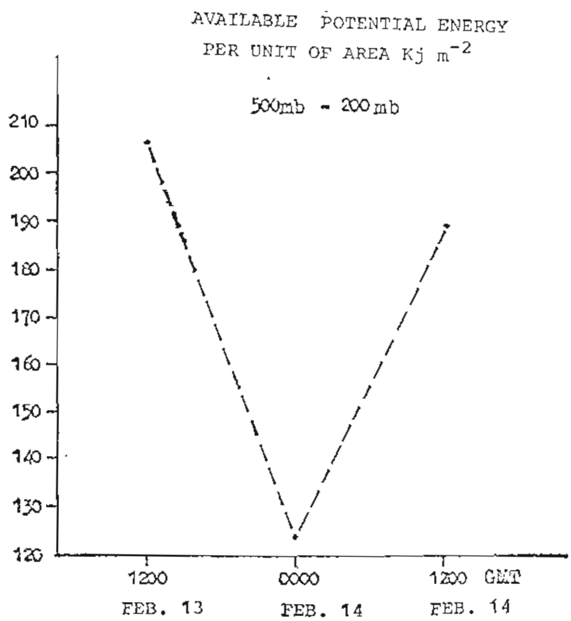
AVAILABLE POTENTIAL ENERGY
PER UNIT OF AREA Kj m-2
500mb - 200mb
210
200
190
180
170
160
150
140
130
120
1200
FEB. 13
0000
FEB. 14
1200 GMT
FEB. 14

Fig. 12

KINETIC ENERGY PER UNIT AREA Kj m^{-2}

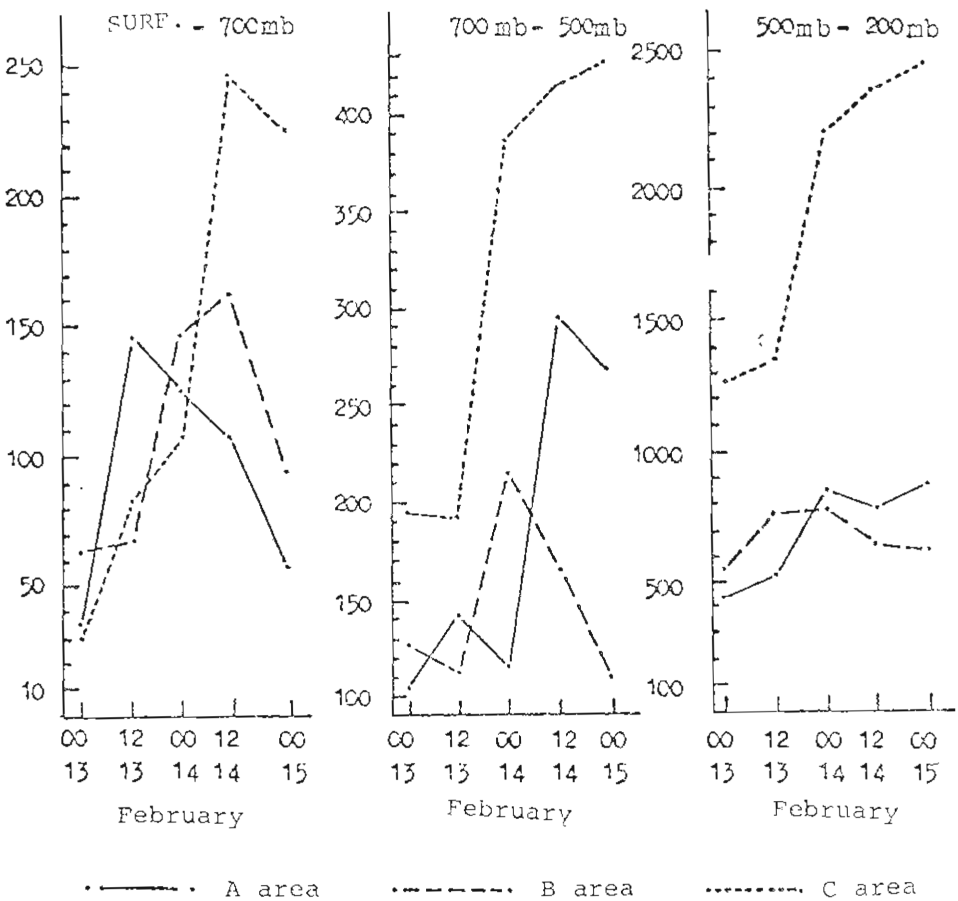

Fig. 13

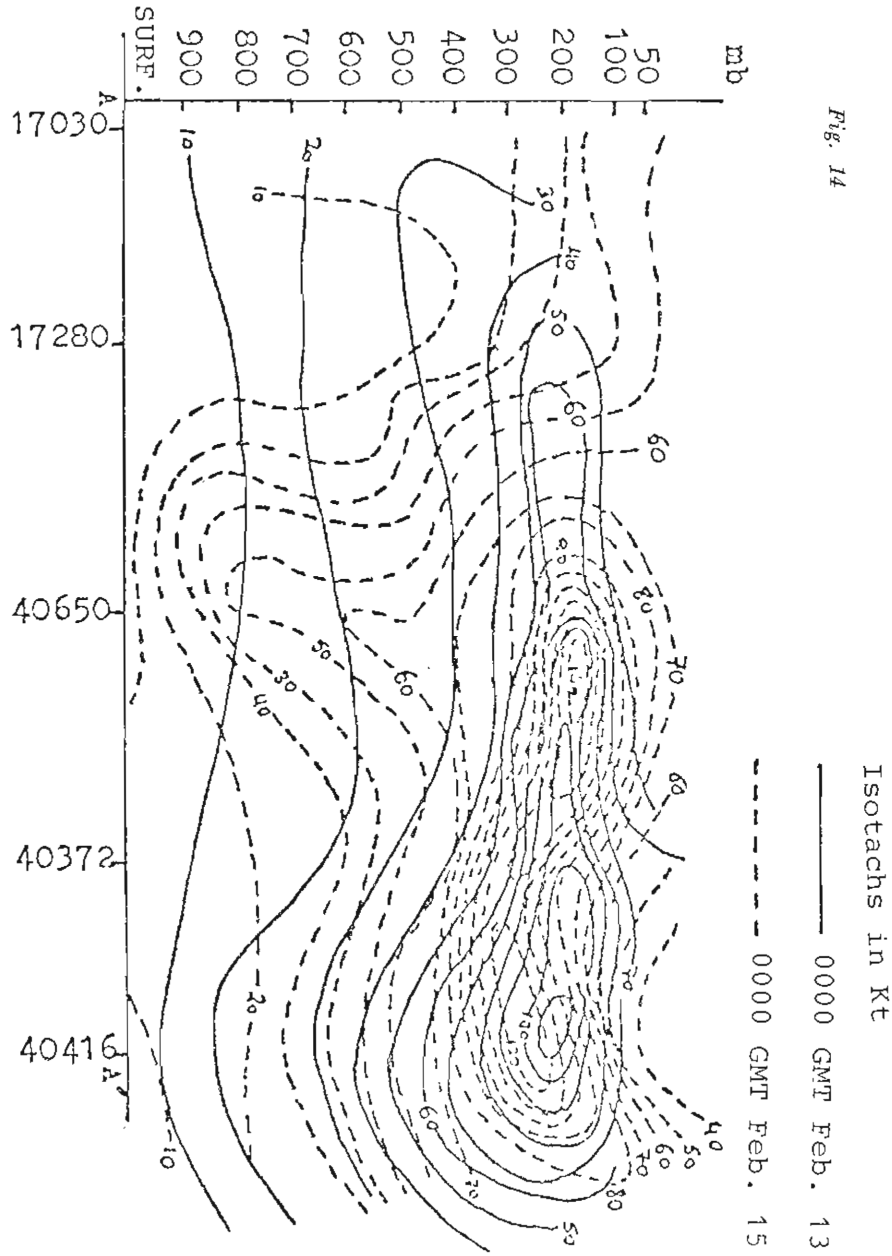
mb
50
100
200
300
400
500
600
700
800
900
SURF.
A
17030
17280
40650
40372
40416
A'
Isotachs in Kt
0000 GMT Feb. 13
0000 GMT Feb. 15

Fig. 14

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ΠΕΡΙΛΗΨΗ

ΔΙΑΓΝΩΣΤΙΚΗ ΜΕΛΕΤΗ ΜΙΑΣ ΧΕΙΜΕΡΙΝΗΣ ΜΕΣΟΓΕΙΑΚΗΣ ΥΦΕΣΕΩΣ

Ὑπὸ

Σ. ΧΡ. ΜΙΧΑΗΛΙΔΗ καὶ Β. Ε. ΑΓΓΟΥΡΙΔΑΚΗ

(Ἐργαστήριο Μετεωρολογίας Ἀριστοτελείου Παν/μίου Θεσ/νίκης)

Μελετῶνται τὰ κύρια στάδια τῆς ἀναπτύξεως μιᾶς χειμερινῆς ὑφέσεως τῆς Μεσογείου. Ἡ κυκλογένεση ἄρχισε περίπου τὴν $06^{\omega}00$ τῆς 10ης Φεβρουαρίου 1980, ἐπάνω ἀπὸ τὶς Βαλεαρῖδες νήσους. Ἡ ὕφεση βαθύνθηκε καὶ κινήθηκε πρὸς ἀνατολὰς ἐπηρεάζοντας τὸν καιρὸ τῆς ἀνατολικῆς Μεσογείου κυρίως, καὶ ἄρχισε νὰ πληροῦται τὴν $00^{\omega}00$ τῆς 14ης Φεβρουαρίου.

Στὴ μελέτη μας αὐτή, δίνεται ἡ διαθέσιμη δυναμικὴ ἐνέργεια καὶ ἡ μετατροπή της σὲ κινητική.

Μὲ τὴ χρήση τῆς κινηματικῆς μεθόδου δίνεται τὸ πεδίο τῶν κατακορύφων κινήσεων.

Γενικά, παρατίθενται ὑπολογισμοὶ ἐπὶ τῆς ἐνεργειακῆς καταστάσεως στὴν περιοχὴ τῆς ὑφέσεως καὶ συνάγονται συμπεράσματα.