METEOROLOGICAL OFFICE M.O. 738

THE METEOROLOGICAL MAGAZINE

Vol. 92, No. 1090, May, 1963

551.515.83:~~551.54.35~~

A 'PRESSURE JUMP' AT MALTA—1 JUNE 1961

By T. H. KIRK

Reference has already been made to the occurrence of 'pressure jumps' at Malta.[1] The present note provides the synoptic background to a particularly good example. All times are in GMT except where otherwise stated.

Figures 1 to 4 show the synoptic situation at the surface at 0001 on 31 May, and 0001, 0600 and 1200 on 1 June. At 0001 on 31 May, a trough of low pressure was evident in the extreme western Mediterranean, associated with a depression over north-west Spain. Pressure was almost uniform over the

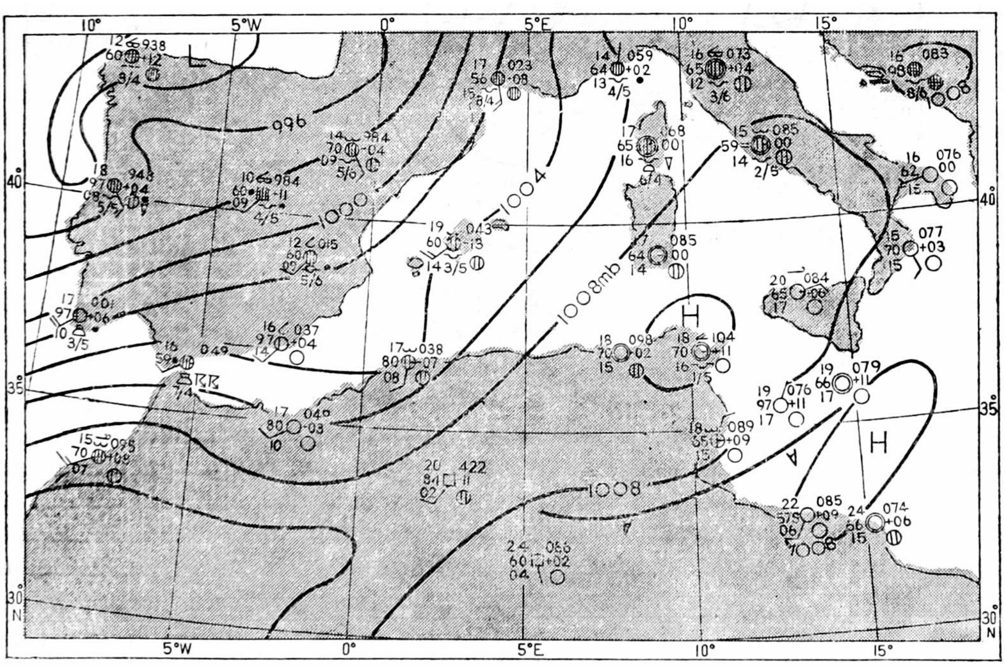


FIGURE 1—SURFACE CHART FOR 0001 GMT, 31 MAY 1961
A——*A* advection discontinuity

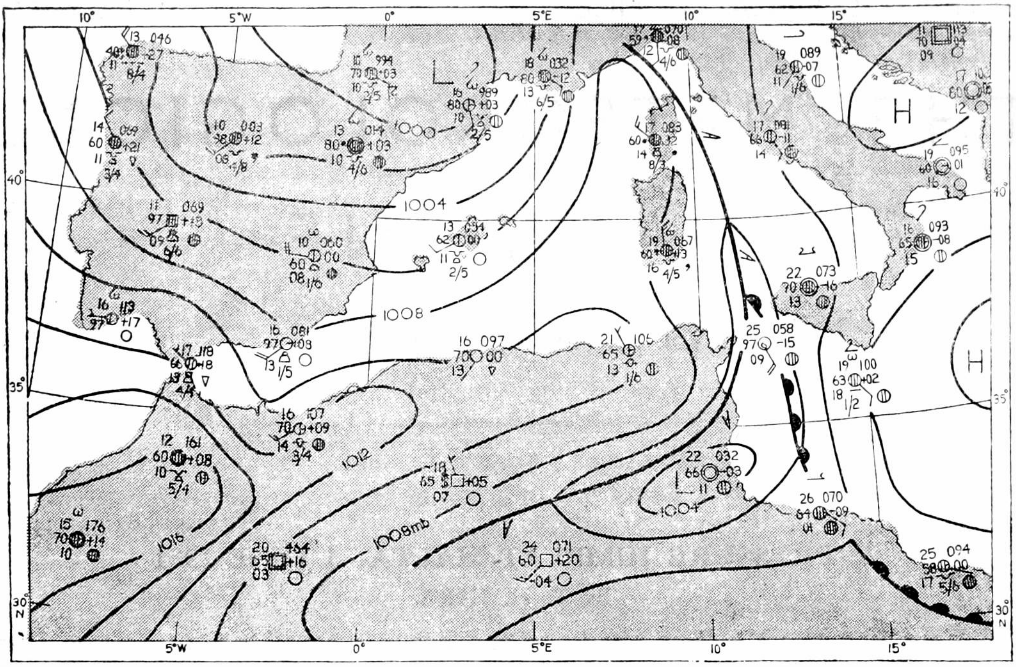


FIGURE 2—SURFACE CHART FOR 0001 GMT, 1 JUNE 1961
A———*A* advection discontinuity

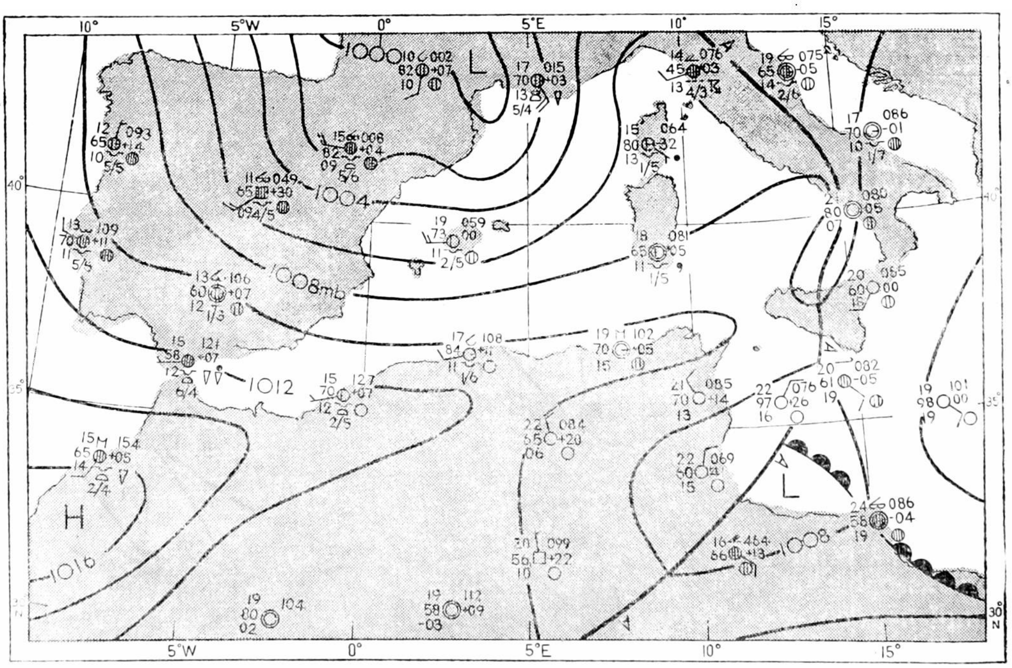


FIGURE 3—SURFACE CHART FOR 0600 GMT, 1 JUNE 1961
A———*A* advection discontinuity

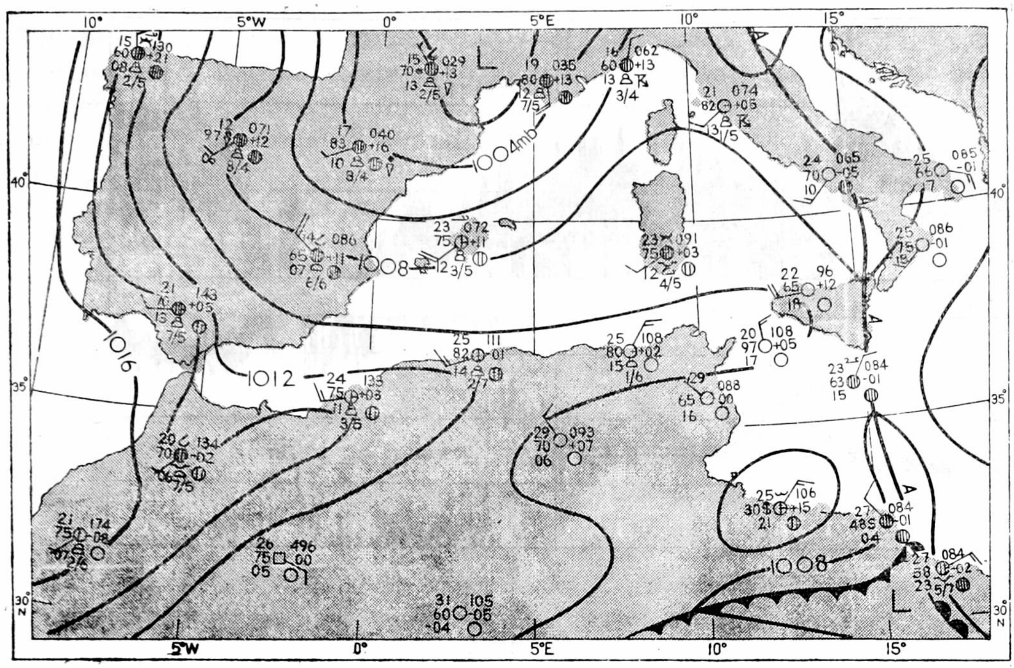


FIGURE 4—SURFACE CHART FOR 1200 GMT, 1 JUNE 1961
A———*A* advection discontinuity

remainder of the Mediterranean. There was a steady eastward motion of this trough accompanied by the formation of a minor secondary depression over eastern Algeria at 1800. At 0001 on 1 June, the main trough extended from east of Corsica to west of Pantelleria and thence south and south-west, the separate centre being no longer in evidence, presumably due to lack of data. At 0600 there is clear evidence of a separate centre to the south-west of Malta with a sharp trough extending from this position to west of Malta, to east of Palermo and thence to east of Rome. It is the passage of this sharp trough which is of interest.

Figure 5 shows the sequence of events at Malta recorded by the autographic instruments on 1 June 1961. A 'pressure jump' occurred at about 0825 local time (GMT + 1 hour) accompanied by marked oscillations of the wind direction. The register of observations at Luqa shows that the pressure rose by 1.7 mb between 0715 and 0745 which confirms the barogram trace. At this time the sky was overcast with cirrostratus, and one-eighth of stratus at 800 feet at 0715 was replaced by one-eighth of stratocumulus at 1200 feet at 0745. The thermogram shows a distinct and abrupt change in the rate of rise of temperature at this time and the hygrogram a sharp and somewhat uneven fall until, at about 1000 local time, when the wind had settled down again very close to its former direction, the humidity decreased to 49 per cent and remained at this figure with only minor variations until 1240 local time. The anemogram shows not only marked variations of wind direction at the passage of the 'jump' but also the very sharp drop in speed which is as characteristic for the anemogram as the sharp pressure rise is for the barogram. On all records, after the passage of the 'jump', there is evidence of small oscillations suggesting wave motion.

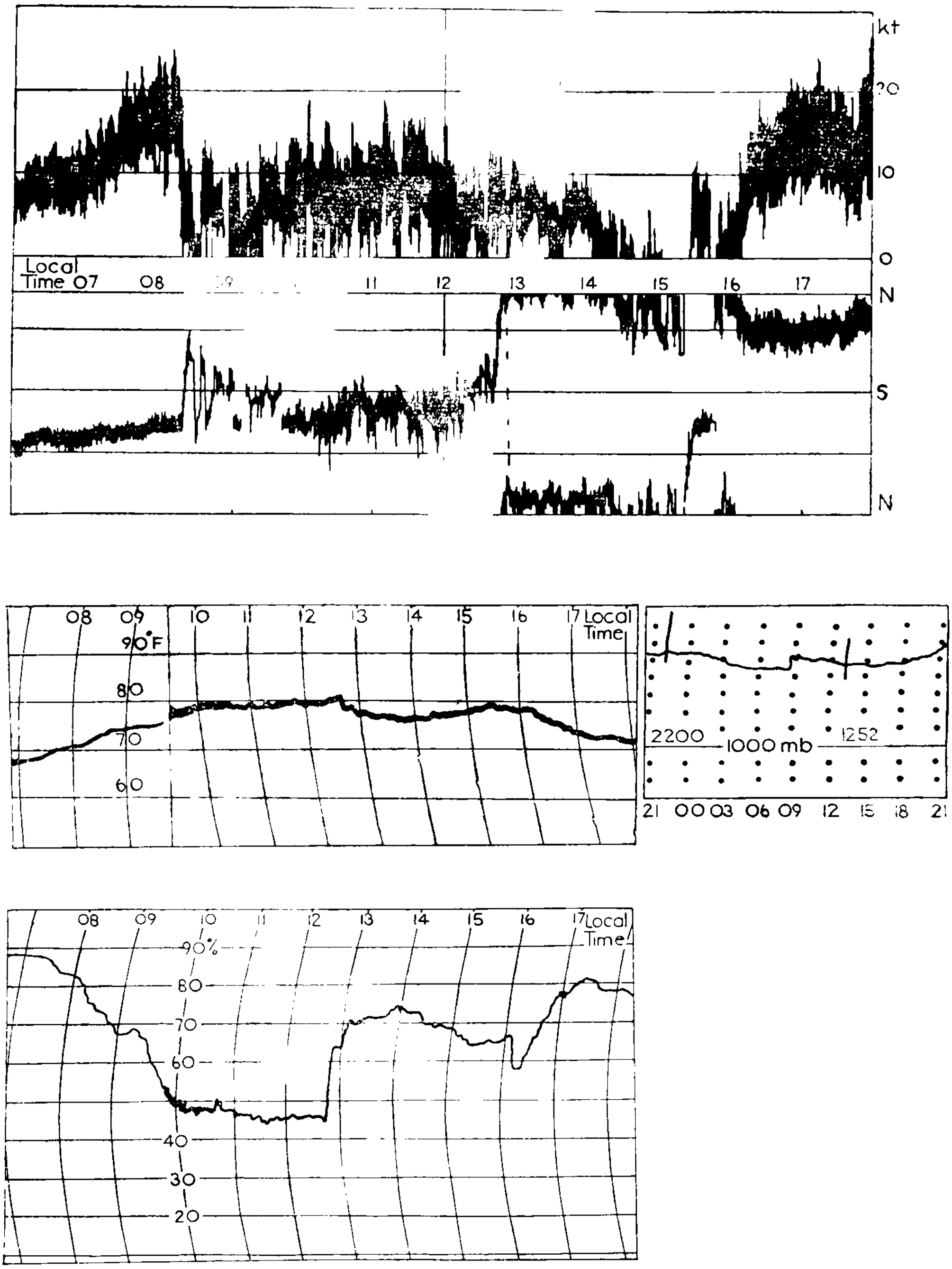


FIGURE 5—PASSAGE OF PRESSURE JUMP AND FRONT AT MALTA, 1 JUNE 1961
Time of pressure jump 0825 approximately, time of front 1240 approximately.
All times are local (GMT + 1 hour).

Anemogram — top chart

Thermogram — middle left

Barogram — middle right

Hygrogram — bottom chart

The next discontinuity, marked *A*———*A* in Figures 1 to 4, 9 to 11, 13 and 14, occurred at approximately 1240 local time, a sharp veer of wind being accompanied by a marked temperature fall of more than 3°F and an accompanying sharp rise of relative humidity to 64 per cent. There was no apparent change in the barogram trace. Except for the lack of barometric evidence this discontinuity had the characteristics of a surface cold front. It is evident that the sequence of events clearly shows two discontinuities in the passage of this trough, first the 'pressure jump' and then the surface cold 'front'.

Before discussing this aspect further it may be profitable to examine the available upper air data. Figures 6 to 8 give the successive upper air ascents at

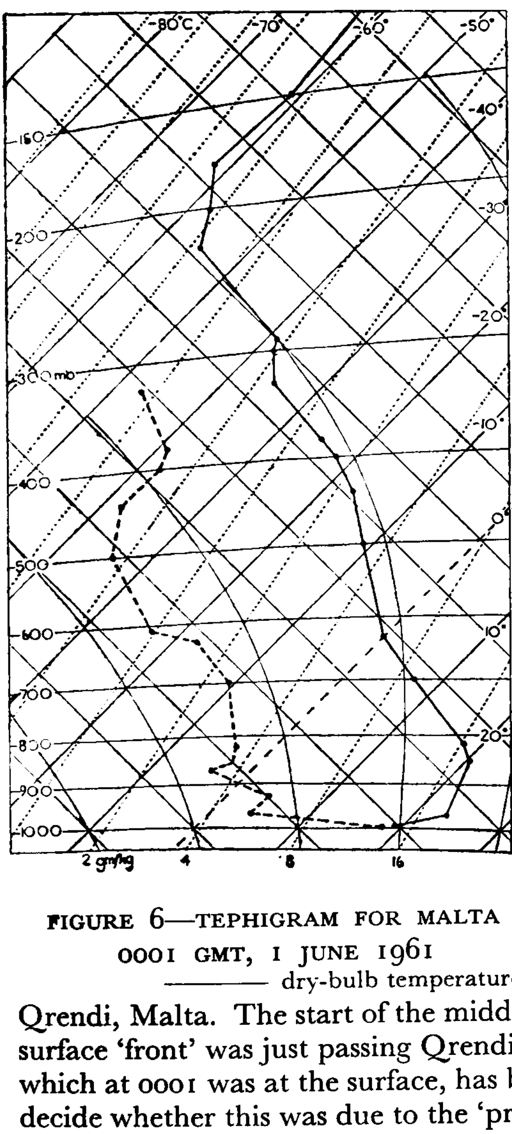


FIGURE 6—TEPHIGRAM FOR MALTA
0001 GMT, 1 JUNE 1961

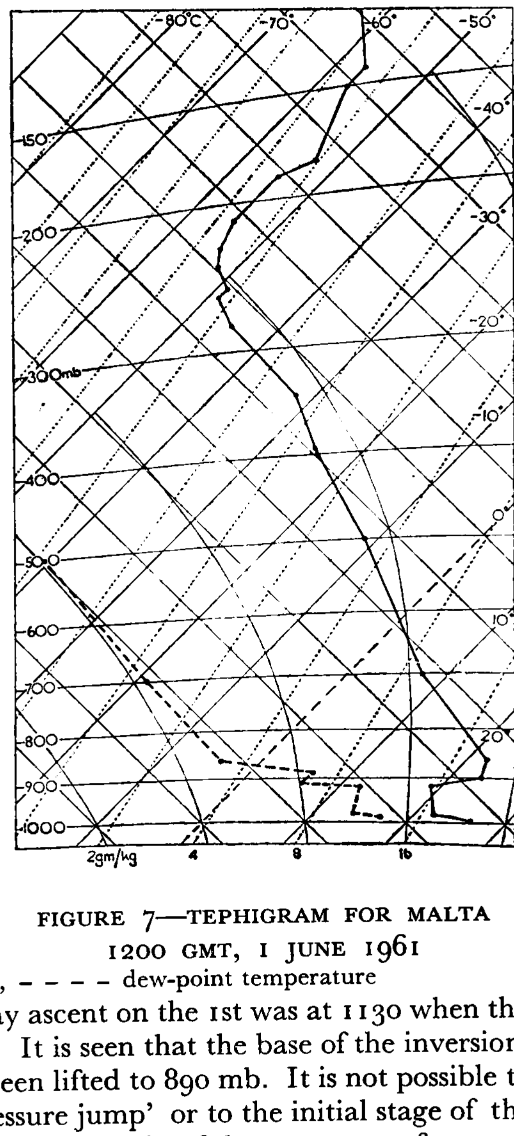


FIGURE 7—TEPHIGRAM FOR MALTA
1200 GMT, 1 JUNE 1961

———— dry-bulb temperature, – – – – dew-point temperature

Qrendi, Malta. The start of the midday ascent on the 1st was at 1130 when the surface 'front' was just passing Qrendi. It is seen that the base of the inversion, which at 0001 was at the surface, has been lifted to 890 mb. It is not possible to decide whether this was due to the 'pressure jump' or to the initial stage of the surface 'front'; nor can the sharp drop in the height of the tropopause from 177 mb to 211 mb strictly be attributed to one or the other discontinuity. It is noted, however, that at most of the lower levels the main temperature fall occurred after 1200 as shown by the subsequent ascents at 0001 and 1200 on the 2nd. The synoptic sequence is given by Figures 9 to 23 at the various levels: 850, 700, 500, 300 and 200 mb.

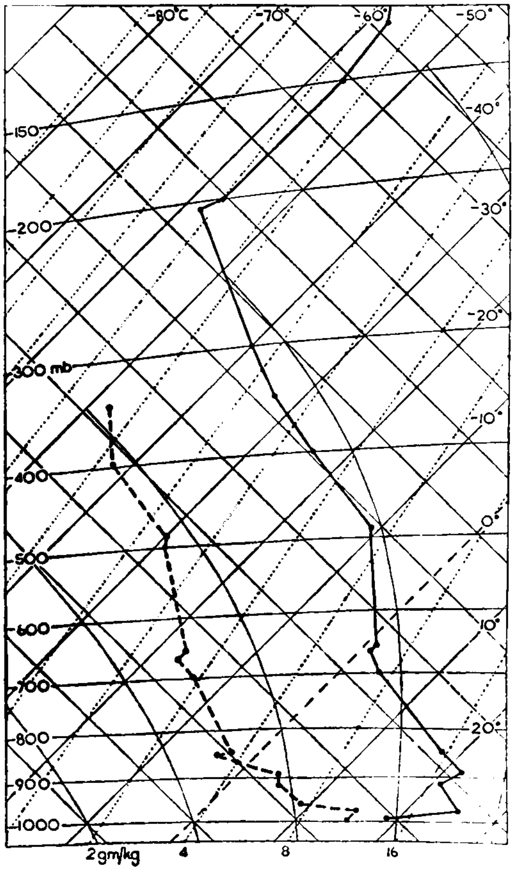


FIGURE 8—TEPHIGRAM FOR MALTA 0001 GMT, 2 JUNE 1961

———— dry-bulb temperature, – – – – dew-point temperature

850 *mb, Figures* 9–11.—At 0001 31 May, the trough in the western Mediterranean was associated with a warm thermal ridge and a tight thermal field extended from eastern Algeria to Greece. At 0001 1 June, a sharp trough had developed behind the position of the surface discontinuity. This is supported by the winds at both Elmas and Marseilles. The wind at Tunis, however, suggests that if this sharp trough existed in this latitude it would be situated somewhere between this station and Pantelleria. At 1200 the advection discontinuity *A*———*A* had just passed Malta and the main trough in the contour field appeared to be still to the west. The temperature at Malta increased from 20°C at 0001 to 21°C at 1200 then fell to 18°C at 0001 on the 2nd and further to 14°C by 1200.

700 *mb, Figures* 12–14.—At 0001 31 May, the main trough in the contour field was over south-west Spain and Morocco and a thermal ridge extended from Tunisia to north-west Spain and southern France. At 0001 1 June, a sharp trough is seen in the contour field just south-west of Sardinia, and strong warm air advection is in evidence not only ahead of the thermal ridge but also at Elmas and Marseilles. The slight cold advection along the Algerian coast suggests the possibility of frontogenetic action in the trough behind the discontinuity as marked.

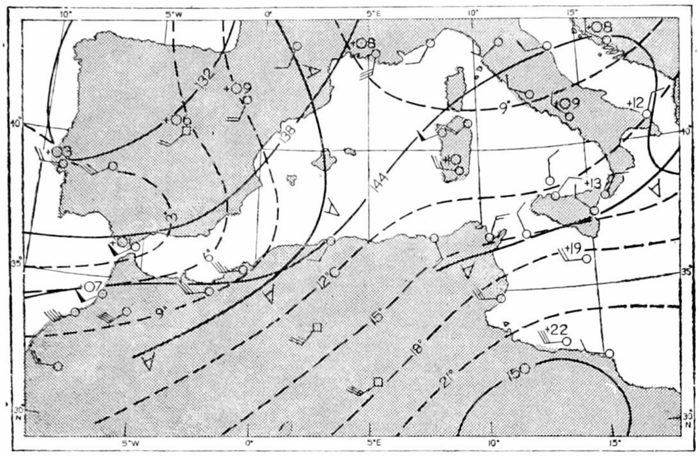


FIGURE 9—850 MB CHART FOR 0001 GMT, 31 MAY 1961
——— contours in geopotential decametres
A▬▬A advection discontinuity, – – – – isotherms

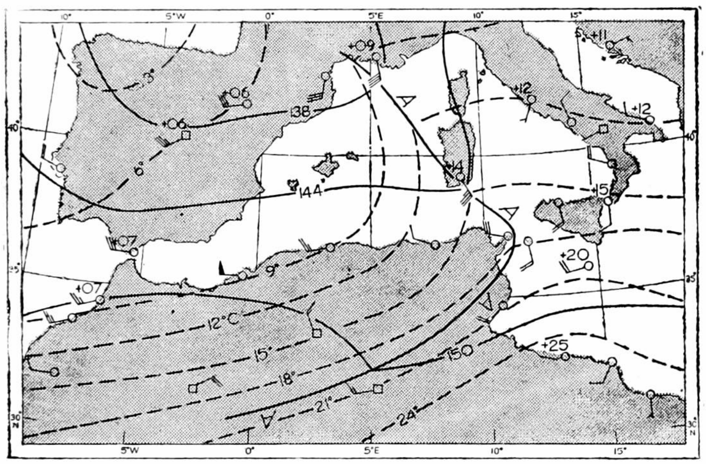


FIGURE 10—850 MB CHART FOR 0001 GMT, 1 JUNE 1961
——— contours in geopotential decametres
A▬▬A advection discontinuity, – – – – isotherms

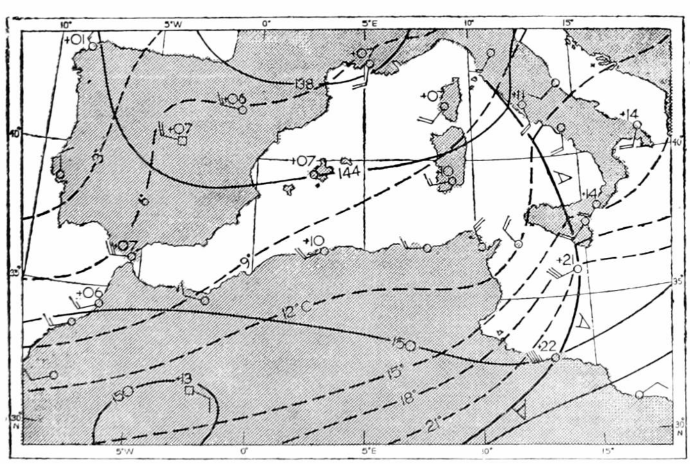


FIGURE 11—850 MB CHART FOR 1200 GMT, 1 JUNE 1961
———contours in geopotential decametres
A▬▬A advection discontinuity, – – – – isotherms

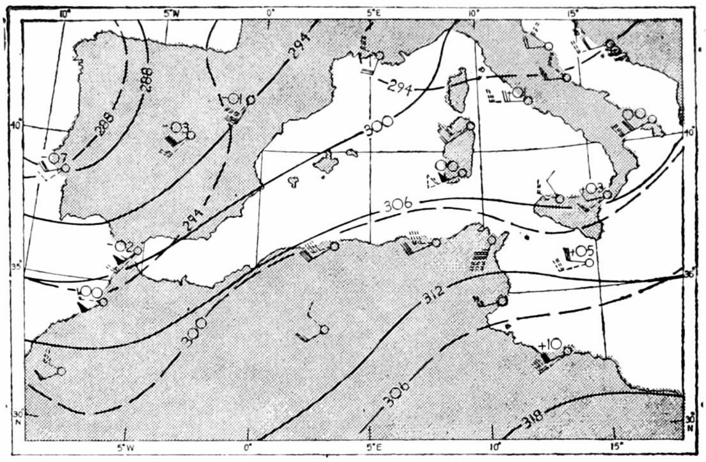


FIGURE 12—700 MB CHART FOR 0001 GMT, 31 MAY 1961
——— contours, —— —— 1000–700 mb thickness, in geopotential decametres

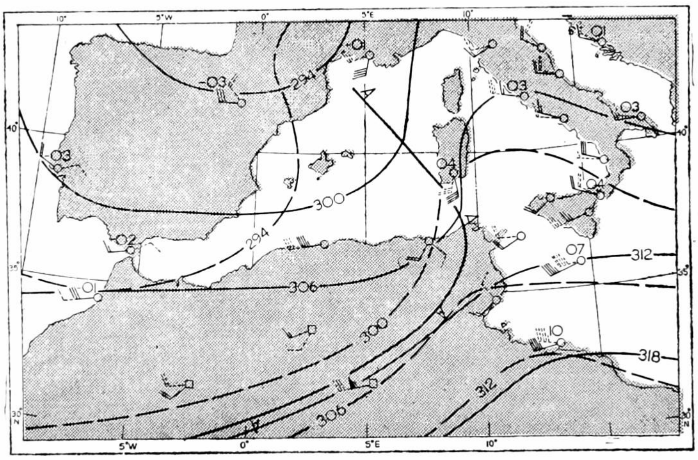


FIGURE 13—700 MB CHART FOR 0001 GMT, 1 JUNE 1961
——— contours, —— —— 1000–700 mb thickness, in geopotential decametres
A———*A* advection discontinuity

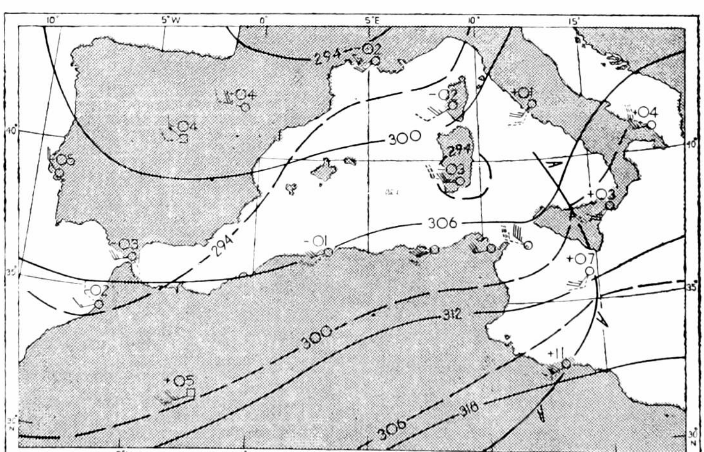


FIGURE 14—700 MB CHART FOR 1200 GMT, 1 JUNE 1961
——— contours, —— —— 1000–700 mb thickness, in geopotential decametres
A———*A* advection discontinuity

At 1200 the cold advection indicated by the wind field at Malta and Idris suggests that the discontinuity should be placed through these stations leaving a trough in the contour pattern behind. As yet, however, there had been no decrease in the temperatures at these places. By 0001 2 June, the temperature at Malta had decreased from 7°C to 4°C and that at Idris from 11°C to 7°C.

500 *mb*, *Figures* 15–17.—At 0001 31 May, the trough in the contour pattern was situated west of the Straits of Gibraltar and a south-west to west flow prevailed over the whole Mediterranean. By 0001 1 June, the surface discontinuity appeared to be associated with a minor thermal trough at 500 mb. Cold advection was occurring ahead of it and strong warm advection behind it. At 1200 this thermal trough appeared to have run ahead of the discontinuity and its passage through Malta might well have corresponded with the pressure jump ahead of the surface discontinuity.

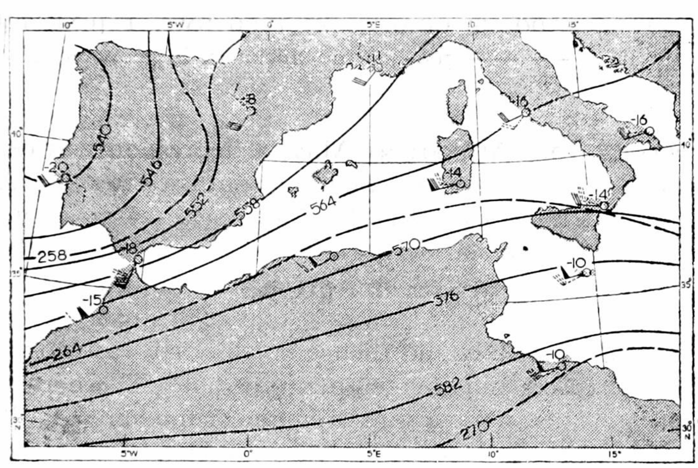


FIGURE 15—500 MB CHART FOR 0001 GMT, 31 MAY 1961
——— contours, — — 700–500 mb thickness, in geopotential decametres

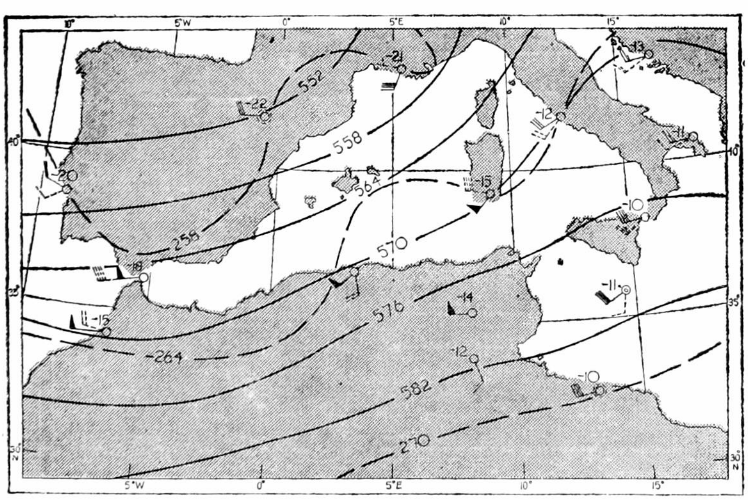


FIGURE 16—500 MB CHART FOR 0001 GMT, 1 JUNE 1961
——— contours, — — 700–500 mb thickness, in geopotential decametres

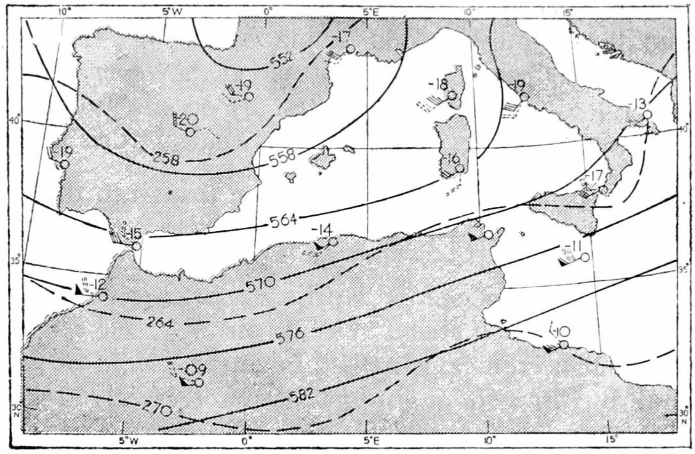


FIGURE 17—500 MB CHART FOR 1200 GMT, 1 JUNE 1961
——— contours, —— —— 700–500 mb thickness, in geopotential decametres

300 *mb, Figures* 18–20.—At 0001 31 May, a depression was centred west of Portugal with an associated trough extending south-westwards. A strong flow, in wave pattern, extended over the Mediterranean with a jet stream from northern Spain to extreme southern Italy to Greece and Turkey. By 0001 1 June, a strong south-west to west flow prevailed from the Straits of Gibraltar to Malta and Tripoli. The main thermal ridge at this time extended from the Sea of Sidra to south-east Italy and thence north-north-eastwards. At 1200 the wind at Malta decreased and the temperature fell 3°C whereas at Idris the wind increased and the temperature remained unchanged. The thickness field pattern (500–300 mb) showed somewhat irregular waves but thermal gradients were small. At 0001 2 June, the discontinuity had become associated with the main thermal trough extending from southern Italy to Cyrenaica.

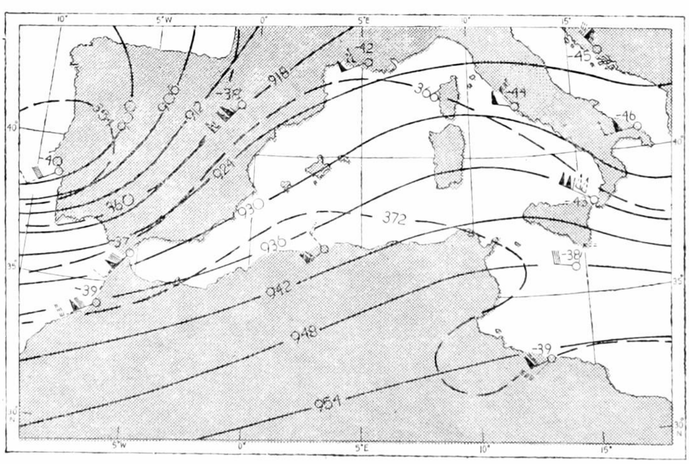


FIGURE 18—300 MB CHART FOR 0001 GMT, 31 MAY 1961
——— contours, —— —— 500–300 mb thickness, in geopotential decametres

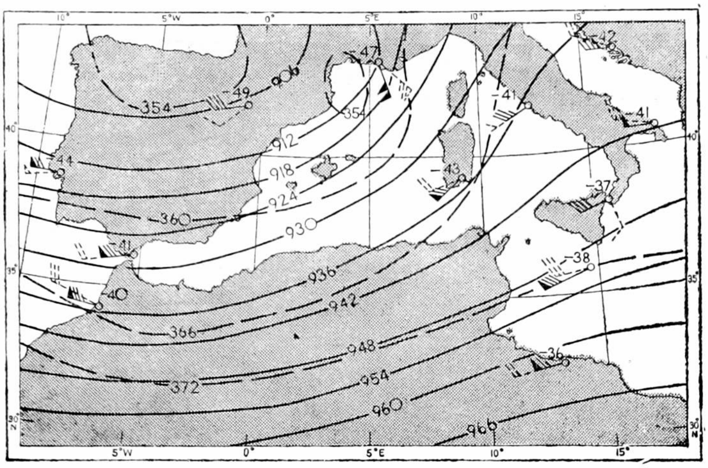


FIGURE 19—300 MB CHART FOR 0001 GMT, 1 JUNE 1961
——— contours, — — — 500–300 mb thickness, in geopotential decametres

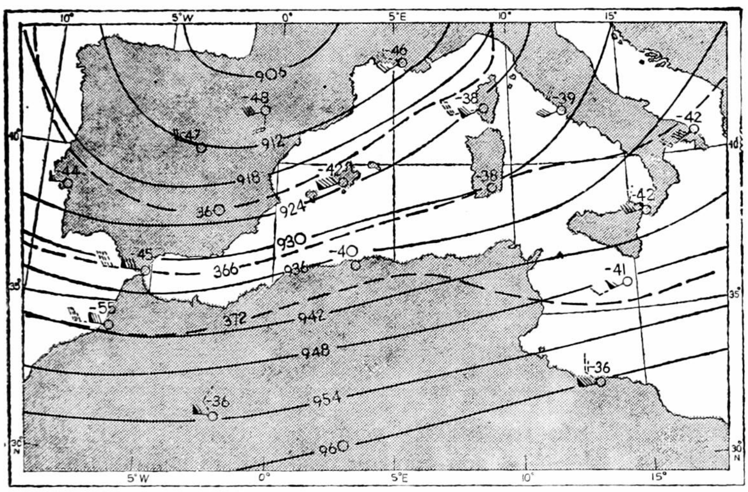


FIGURE 20—300 MB CHART FOR 1200 GMT, 1 JUNE 1961
——— contours, — — — 500–300 mb thickness, in geopotential decametres

200 *mb, Figures* 21–23.—At 0001 31 May, the contour pattern was very similar to that at 300 mb but the thermal pattern over the central Mediterranean was most irregular and a sharp thermal trough was situated between Malta and Idris where a wind of 105 knots was observed, compared with 40 knots at Malta. At 0001 on the 1st, the main area of low thickness values (300–200 mb) extended from northern Italy through Yugoslavia to Cyrenaica, well ahead of the surface discontinuity as shown by the thermal wind at Malta. There was still evidence of a thermal trough between Malta and Idris although the light thermal wind at Idris suggests that it was much weaker. At 1200 the main thermal trough appeared to be associated with the surface discontinuity.

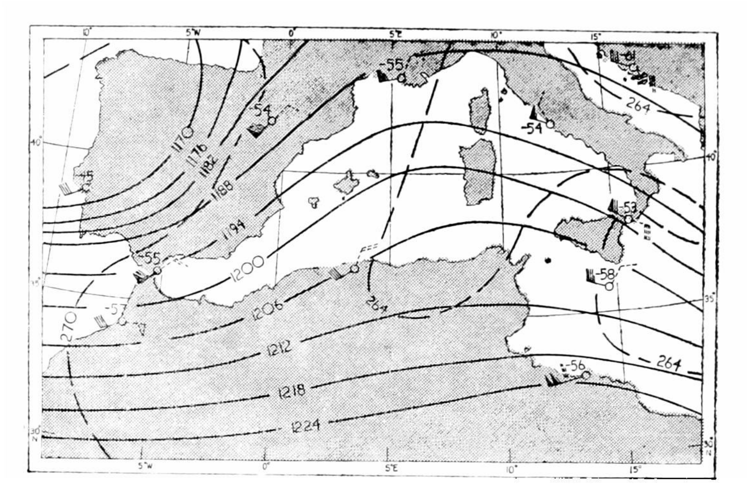


FIGURE 21—200 MB CHART FOR 0001 GMT, 31 MAY 1961
——— contours, —— —— 300–200 mb thickness, in geopotential decametres

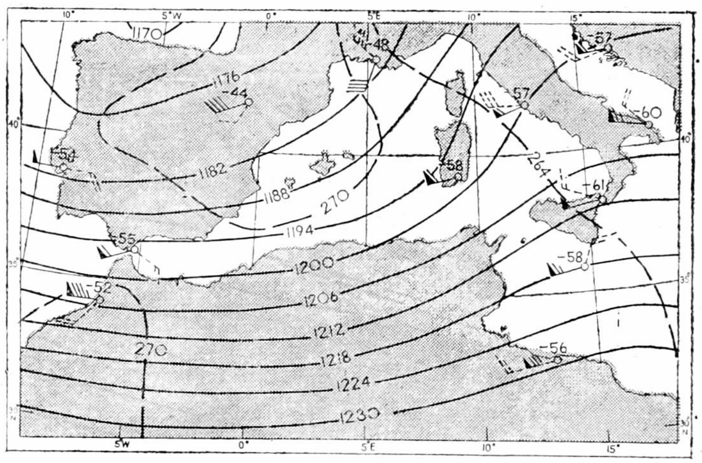


FIGURE 22—200 MB CHART FOR 0001 GMT, 1 JUNE 1961
——— contours, —— —— 300–200 mb thickness, in geopotential decametres

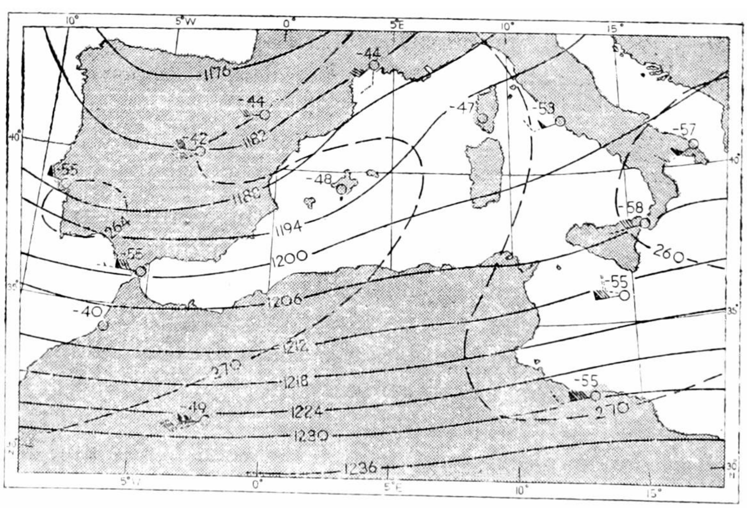


FIGURE 23—200 MB CHART FOR 1200 GMT, 1 JUNE 1961
——— contours, —— —— 300–200 mb thickness, in geopotential decametres

Conclusions.—Can any conclusions be drawn from this example? First of all, it would appear that the pressure jump has prognostic value for the subsequent passage of the surface cold discontinuity. The pressure jump occurred when a near-surface inversion was present and the height of the inversion was subsequently increased. The time of the upper air ascent at Qrendi (1130) does not permit an unambiguous distinction to be made between the changes accompanying the pressure jump and those due to the surface discontinuity, but it appears most probable that the sharp decrease in height of the tropopause occurred at the time of the pressure jump and that subsequent ascents (after 1200) showed the effect of the advection discontinuity by the continued decrease of temperature at most heights in the lower troposphere. This viewpoint is perhaps supported by the complete lack of evidence in the barogram for an advection discontinuity passing Malta although its presence at the surface was well attested by a sharp fall of temperature. These facts do not seem to lend much support to Tepper's[2] view of the surface front functioning mechanically as a piston to produce a shock wave on the inversion surface.

The evidence afforded by the charts shows that at 500 mb the thermal wave pattern was out of phase with that at 700 mb and at the time of passage of the surface discontinuity ('front') the 500 mb trough was certainly ahead of the latter. In seeking for explanations of the pressure jump we have two interesting possibilities, suggested by this example, in addition to the change in the low-level inversion of whose relevance we are already aware.[2] They are

(i) the sharp drop of tropopause height and

(ii) the occurrence of out-of-phase relationships at different levels.

REFERENCES

1. KIRK, T. H.; "Pressure jumps" at Malta. *Met. Mag., London,* **90,** 1961, p. 206.
2. TEPPER, M.; A proposed mechanism of squall lines: the pressure jump line. *J. Met., Lancaster, Pa.,* **7,** 1950, p. 21.

551.551.5:551.558.21:629.13

TURBULENCE NEAR DERNA ON 21 MARCH 1962

By M. GRIMMER

On 21 March 1962 a Shackleton aircraft was en route from Aden to Malta, having been diverted from El Adem because of strong cross winds on the runways.

At about 0600 GMT, 10 minutes after crossing the coast near Derna, the aircraft was in clear air at 4500 feet at position 33°05'N 22°15'E when, without any change in power setting, the airspeed increased from 140 to 200 knots and a slight climb was recorded. Almost immediately severe turbulence was suddenly encountered, culminating in three extemely severe bumps, in which 500 feet of altitude were lost, loose objects hit the roof, and radio contact with Malta was lost. The captain had no time to take any action before conditions became smooth again and the aircraft reached Malta without encountering any more than slight turbulence. On arrival the captain requested an airframe inspection, because he suspected damage to the main wing spars. He described the turbulence as far more severe than he had ever experienced, even in cumulonimbus.

For some time before crossing the coast, and up to the time of the incident, the navigator had found winds varying little from 220° 50 knots, measured by

Doppler radar. However, immediately afterwards he found a wind of 310° 15 knots, which quickly backed and strengthened to the previous value and little further change was found en route to Malta. The navigator was surprised at finding a north-west wind and rechecked it, so that it may be considered reliable.

At the time a surface depression of 994 mb was moving slowly in the Sicilian narrows and a strong southerly flow affected Cyrenaica ahead of an associated trough. At 0600 GMT a mean surface wind speed of 30 knots was reported from the south-south-east at El Adem with rising sand, while at Derna some 75 miles to the north-west, the wind was very light easterly, which clearly indicates the profound disturbance generated in a southerly flow by the high ground of Cyrenaica, which is generally above 1500 feet and reaches 2500 feet in places. (See Figure 7 on page 151.)

Aloft the winds over Cyrenaica were generally strong westerlies and above 10,000 feet the 0600 GMT winds at Tobruk showed a gradual veer and increased to 110 knots at 40,000 feet. However the lower winds revealed a more interesting structure with a subsidiary maximum of 190° 51 knots at 3000 feet decreasing and veering to 220° 26 knots at 10,000 feet. These winds agree well with those found by the navigator in the region of the coast.

A complex situation clearly existed at the time of the incident, and it is improbable that the turbulence is attributable to any single factor. However, certain effects may be mentioned as possible contributory factors:

1. Lee waves are suggested by the initially smooth build up of height and air speed of the Shackleton, but an examination of observations shows that conditions were far from ideal for their formation, because:
   (i) The winds, although increasing with height, were only perpendicular to the ridge below 10,000 feet.
   (ii) The Tobruk ascent for 0001 GMT on 21 March showed an inversion from the surface up to about 2000 feet (which is below ridge height) and conditional instability above that. Thus the l^2 parameter (Corby[1]) satisfies the lee-wave condition only because its values beneath the inversion were large, and not, as in the ideal case, because there is a deep stable layer whose top well exceeds the height of the ridge.
2. The facts that surface winds at Derna were light despite the strong southerly gradient, and that the aircraft experienced a north-west wind shortly after the incident indicate that a strong horizontal eddy was set up in the lee of the high ground.
3. Even if lee waves were not present, it is almost certain that a turbulent wake existed to the north of the high ground. Vertical turbulence would therefore be expected, but in the absence of some other mechanism it seems unlikely that turbulence of the type expected could be propagated as far upwind in the lee of the ridge, and to a height above ridge level.

It is not known whether an incident of this sort has been reported before, but it seems probable that it must occur to some degree in any strong southerly surface stream over Cyrenaica. It is the more hazardous to aircraft since dryness and therefore cloudlessness is a property of such airstreams and turbulence of any sort may be unexpected.

REFERENCE

1. CORBY, G. A.; Air flow over mountains. *Met. Rep., London*, **3**, No. 18, 1957.

551.543.5:551.551.5:551.558.21

SOME SYNOPTIC FEATURES OF AN OCCURRENCE OF LOW-LEVEL TURBULENCE

By T. H. KIRK

The incident, described by Grimmer,[1] in which an aircraft encountered severe low-level turbulence in clear air off the coast of Cyrenaica is particularly interesting because, in this instance, there is additional evidence which suggests that any explanation based solely on lee effects cannot be entirely adequate.

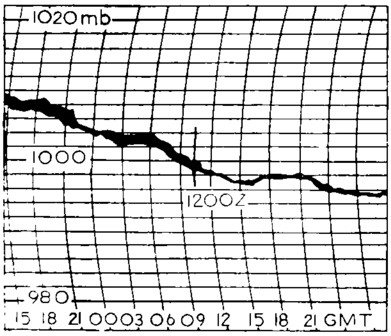
It is, of course, well known that severe turbulence does occur in waves to the lee of high ground. Quoting from a World Meteorological Organization Technical Note:[2] "Although flight through mountain waves may be deceptively smooth even when strong vertical currents are operating, it may also involve turbulence of an intensity as great as that generated in the worst thunderstorms."

Corby[3] also writes: "The rotor zone gives rise to the most severe turbulence to be found in the airflow over mountains and on occasions may be more violent than that occurring in the worst thunderstorms."

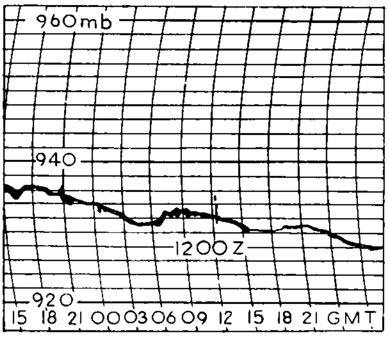
Sufficient evidence exists therefore for accepting the possibility of severe turbulence in mountain waves without seeking further causes. It is usual, however, to associate the worst turbulence with the first rotor zone, i.e. relatively close to the mountain. In this occurrence[1] the turbulence was encountered some 25 miles off the coast and this, in itself, is perhaps sufficient to suggest the possibility of other causative factors. That wave flow can break down suddenly giving rise to turbulence is well known:[3] "It appears that sometimes this breakdown operates simultaneously throughout the entire depth of the wave system and it may be associated with slight changes in the characteristics of the airstream when conditions are near the critical for waves to occur."

Synoptic evidence will be presented to show that a significant variation of the flow did in fact occur. One might accept the view that this variation could be responsible for the breakdown of the lee waves into turbulence as suggested above. On the other hand it may be that the variation is in itself a sufficient reason for severe turbulence and that the effect of the high ground is only of a contributory nature.

Figure 1 shows barograms for Derna — position 32°44'N, 22°38'E, height above M.S.L. 30 feet, and Shahat (Cyrene)—position 32°49' N, 21°51' E,



Derna



Shahat (height 2027 feet)

FIGURE 1—BAROGRAMS FOR DERNA AND SHAHAT, 21 MARCH 1962

height above M.S.L. 2027 feet. The Derna record, although a poor one, does show pronounced evidence of wave motion. It cannot, however, be assumed that the wave motion is due to lee waves of the normal type. The upper air ascent for Tobruk at 1200 GMT, 21 March 1962 (Figure 2) suggests the presence of a shallow inversion just below 900 mb (at about 3000 feet) and it is well established that wave motion can occur at inversions in the absence of the

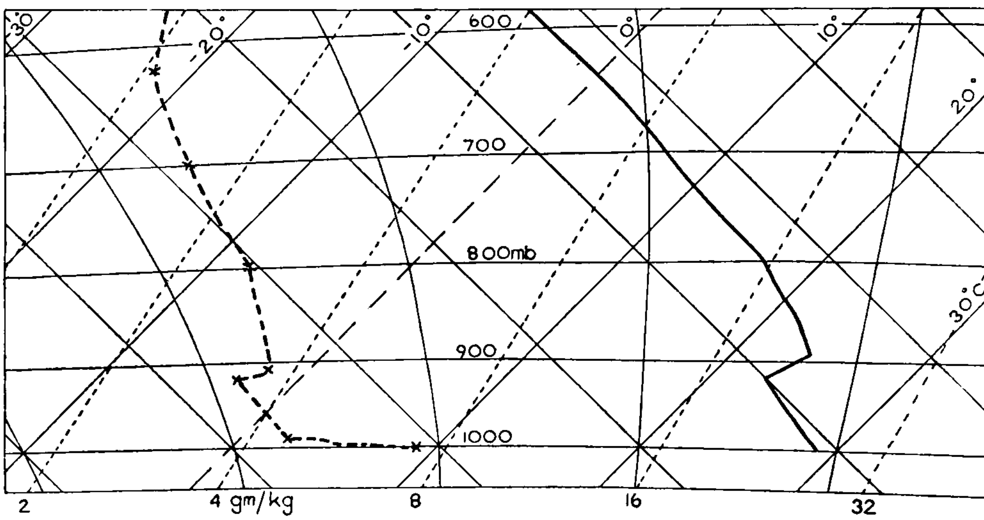
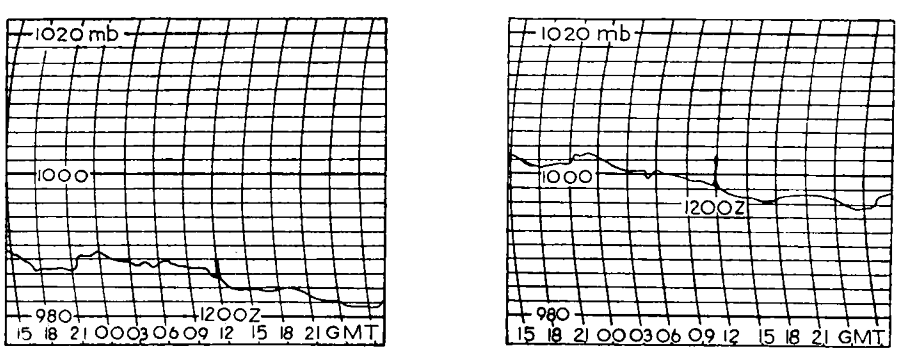


FIGURE 2—TEPHIGRAM FOR TOBRUK 1200 GMT, 21 MARCH 1962
——— dry-bulb temperature, – – – – dew-point temperature

disturbing influence of high ground. In fact, the presence of two quasi-autobarotropic layers separated by a shallow inversion provides the necessary conditions for the application of the hydraulic analogy.[4] The occurrence of gravity waves is therefore readily explicable and it is probable that the waves shown on the barometric record at Derna are of this origin.

Figure 3 shows the barograms for Benina—position 32° 44′N, 20°16′E, height above M.S.L. 425 feet, and Agedabia—position 30° 43′N, 20°10′E,

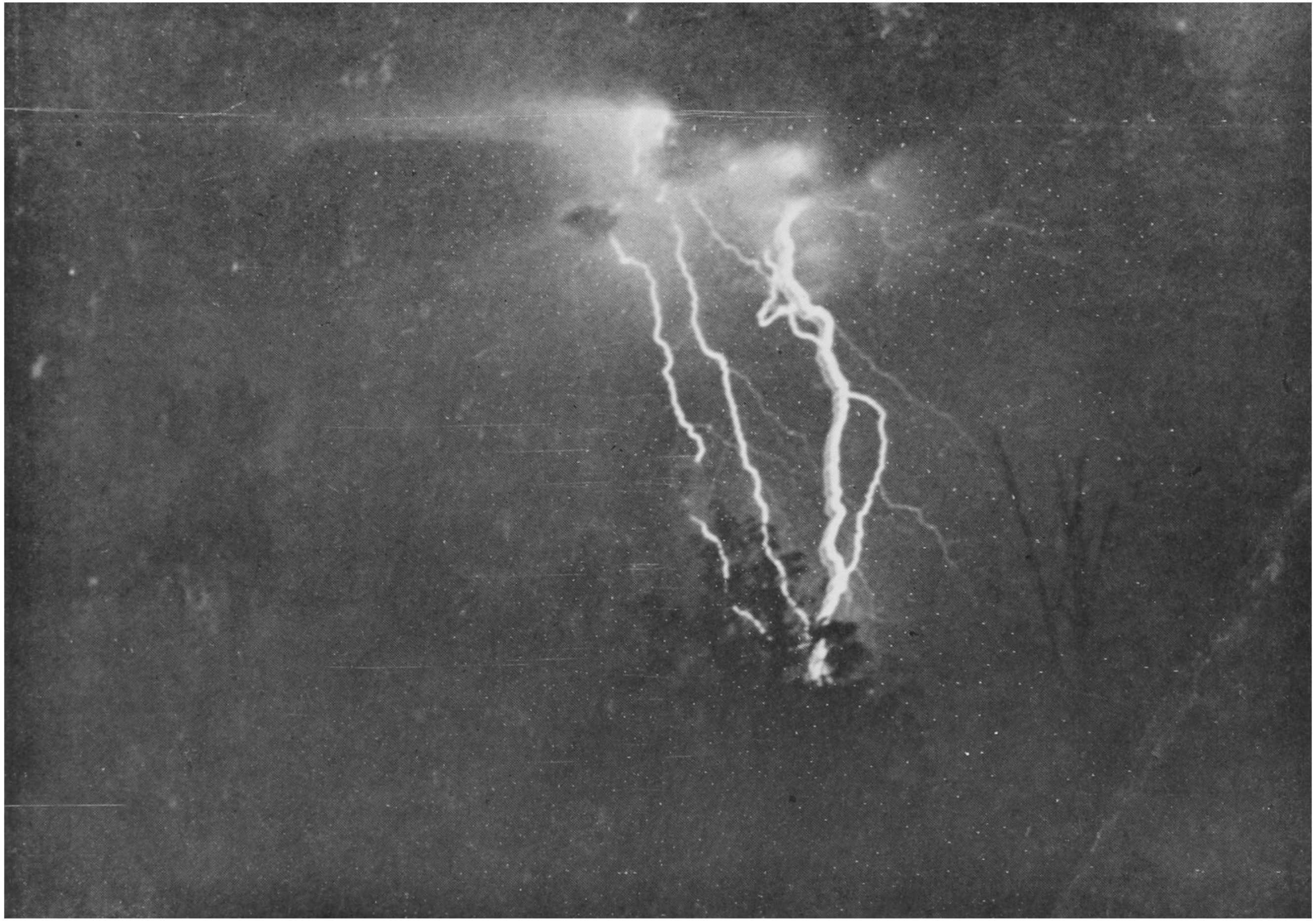


Benina — Agedabia

FIGURE 3—BAROGRAMS FOR BENINA AND AGEDABIA, 21 MARCH 1962, SHOWING PRESSURE JUMPS

BIRMINGHAM (EDGBASTON) AUXILIARY REPORTING STATION

Mr. A. L. Kelley, Director of the Edgbaston Observatory is standing beside the screens. The anemometer can be seen on the distant tower just to the right of the screens. Continuous records have been maintained here since 1887.



Photograph by P. T. Hutton

EXAMPLES OF LIGHTNING AT CHANGI, APRIL 1956

The lightning flashes shown in these photographs are not uncommon during the thunderstorm season at Changi. Time exposure 30 seconds.

Photograph by P. T. Hutton

EXAMPLES OF LIGHTNING AT CHANGI, APRIL 1956

The lightning flashes shown in these photographs are not uncommon during the thunderstorm season at Changi. Time exposure 30 seconds.

To face p. 149

FLEETWOOD (LANCASHIRE) COASTGUARD LOOKOUT

Situated on the sand dunes alongside the beach, on the west side of the town. Meteorological observations began on 1 January 1961.

height above M.S.L. 15 feet. Of immediate interest are the pressure jumps at or near 2100 GMT on 20 March. These afford confirmation of the occurrence of gravity waves at an interface and are direct evidence of a disturbance in the airflow independent of the topography. Before commenting on the origin of these pressure jumps it may be useful to examine the synoptic situation.

Figure 4 shows the surface chart for 2100 GMT on the 20th. The line marked *A - - - A - - - A* is not a front according to temperate–latitude usage but an advection discontinuity. It has been drawn to be consistent with the passage of the pressure jumps at Benina and Agedabia. It may be regarded as a 'pressure jump' line[4] and, across it, the isobars have been drawn 'discontinuous' in the manner already used by Freeman.[5] The subsequent situations at 0001, 0300, 0600 and 0900 GMT are shown in Figures 5, 6, 7 and 8 respectively.

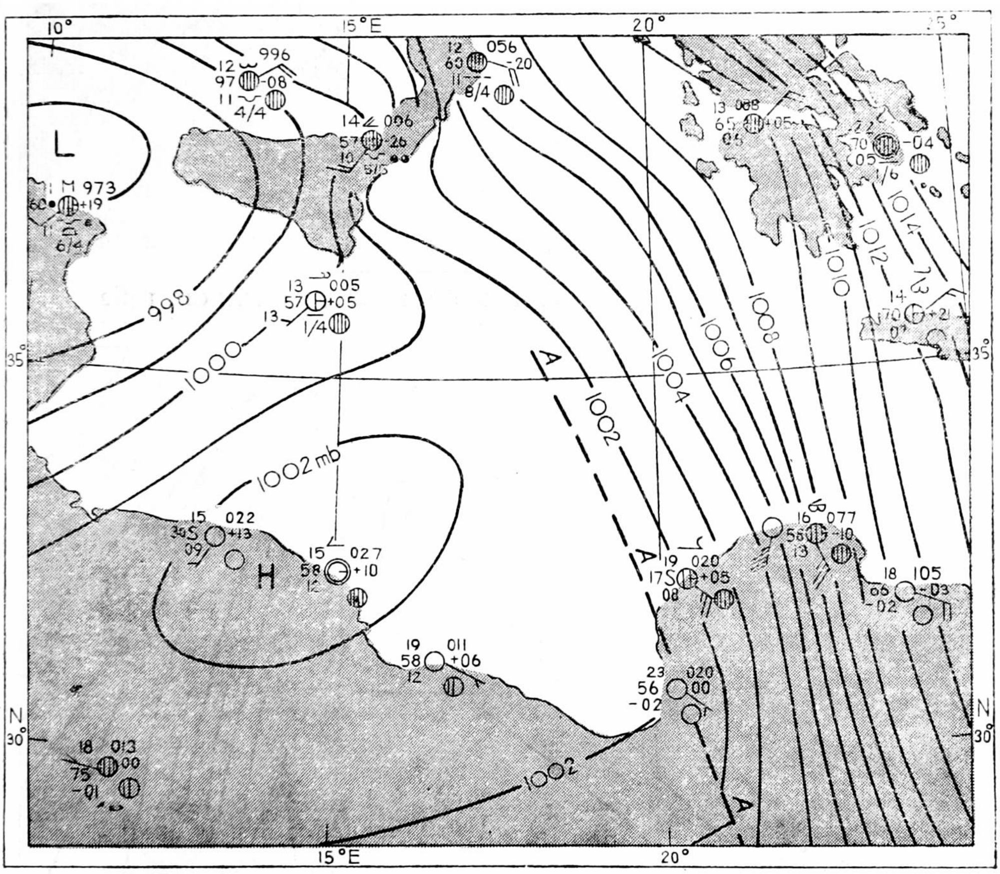


FIGURE 4—SURFACE CHART FOR 2100 GMT, 20 MARCH 1962
A - - - - A advection discontinuity

The sparsity of the evidence for adopting this procedure is appreciated and for this reason it is necessary to consider the 850 mb charts for 1200 GMT on the

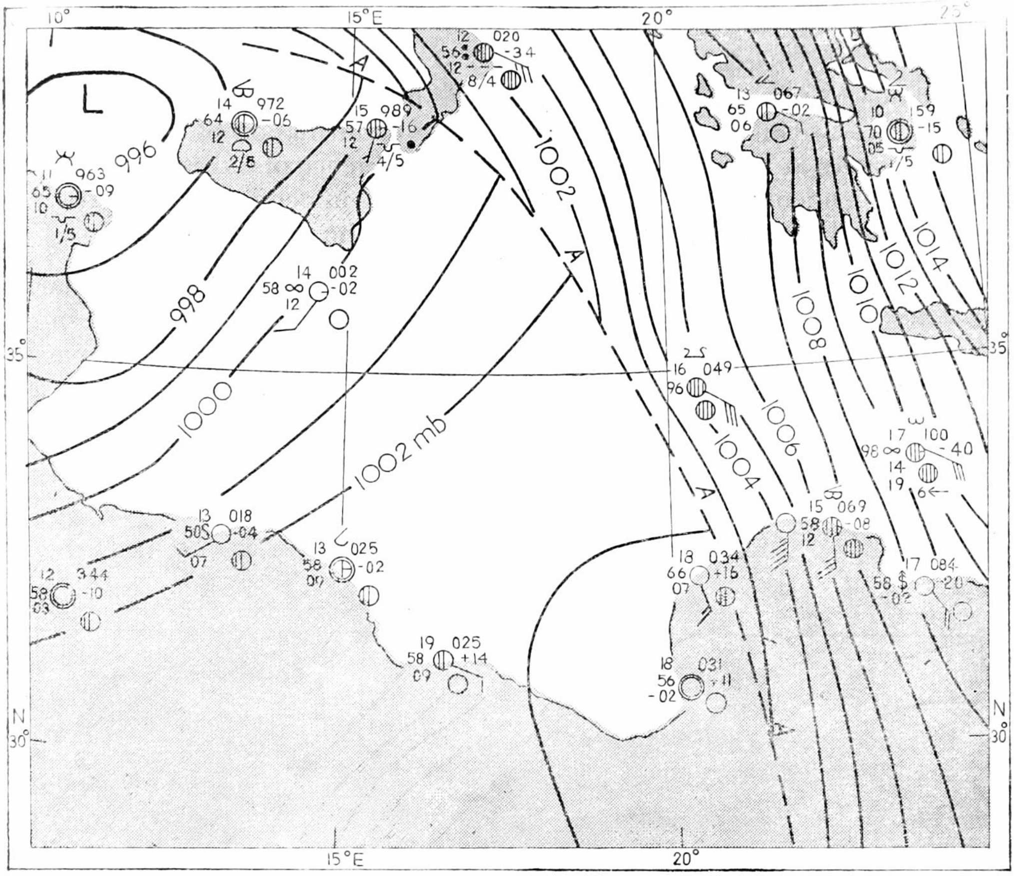


FIGURE 5—SURFACE CHART FOR 0001 GMT, 21 MARCH 1962

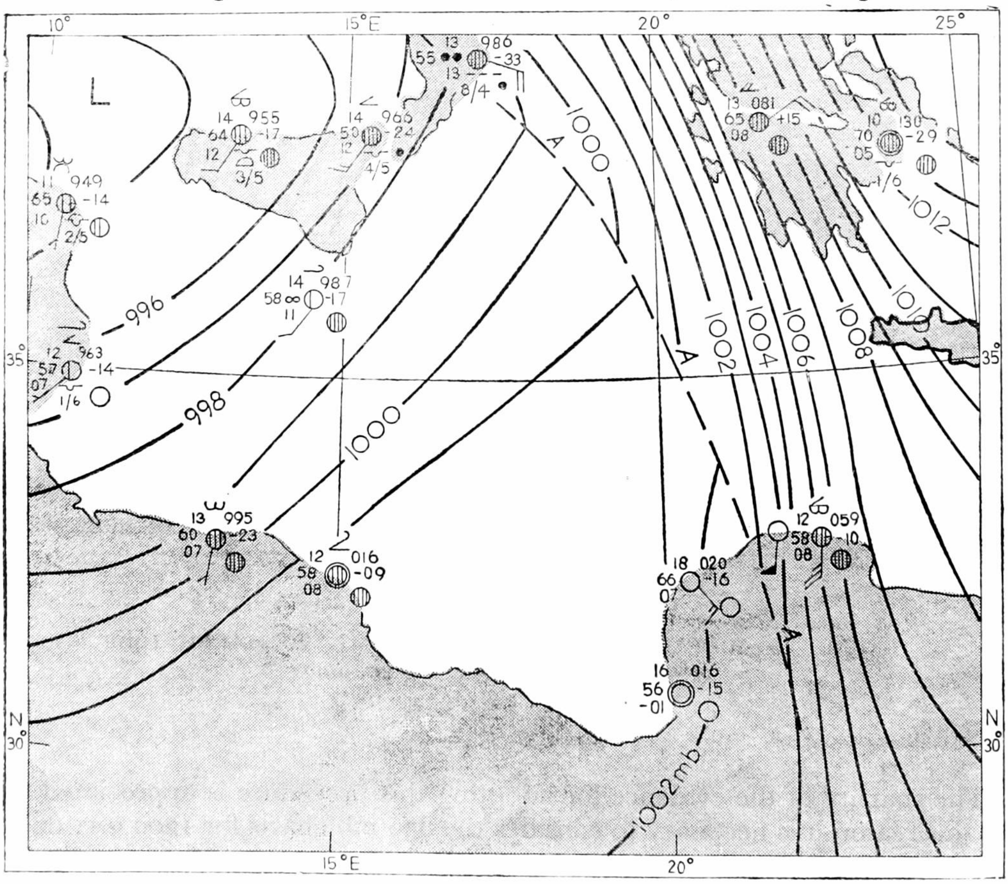


FIGURE 6—SURFACE CHART FOR 0300 GMT, 21 MARCH 1962

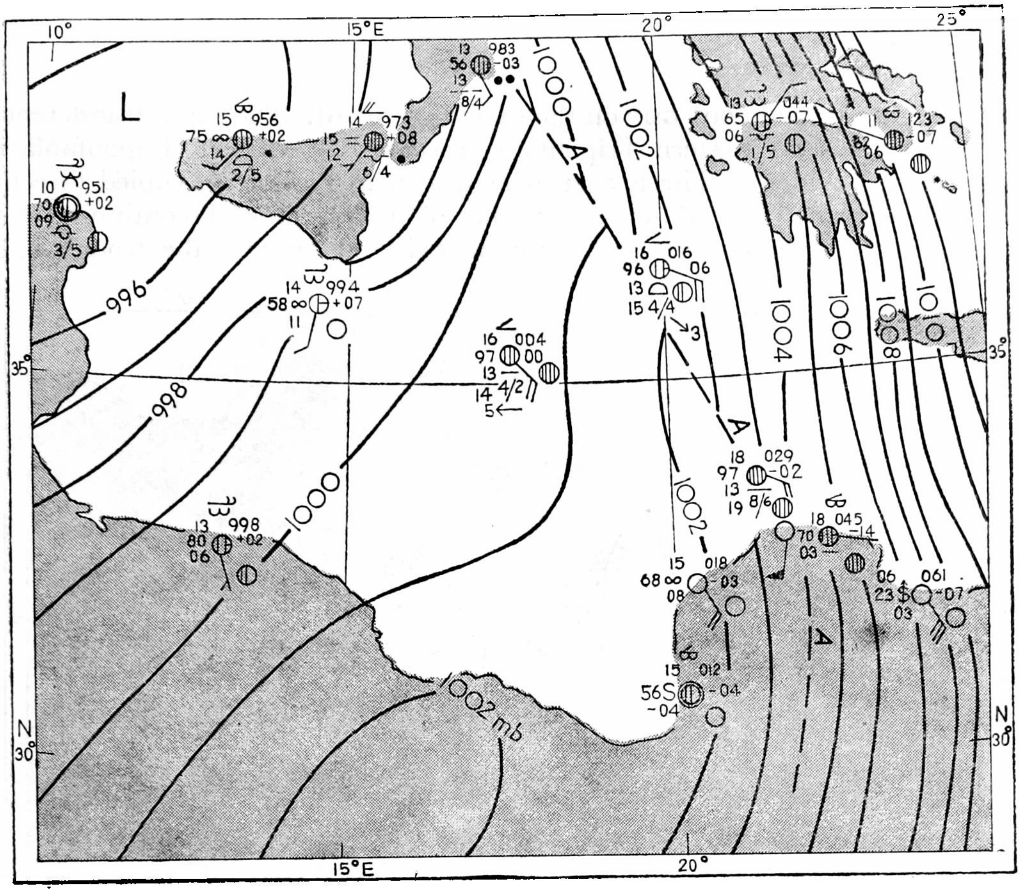


FIGURE 7—SURFACE CHART FOR 0600 GMT, 21 MARCH 1962

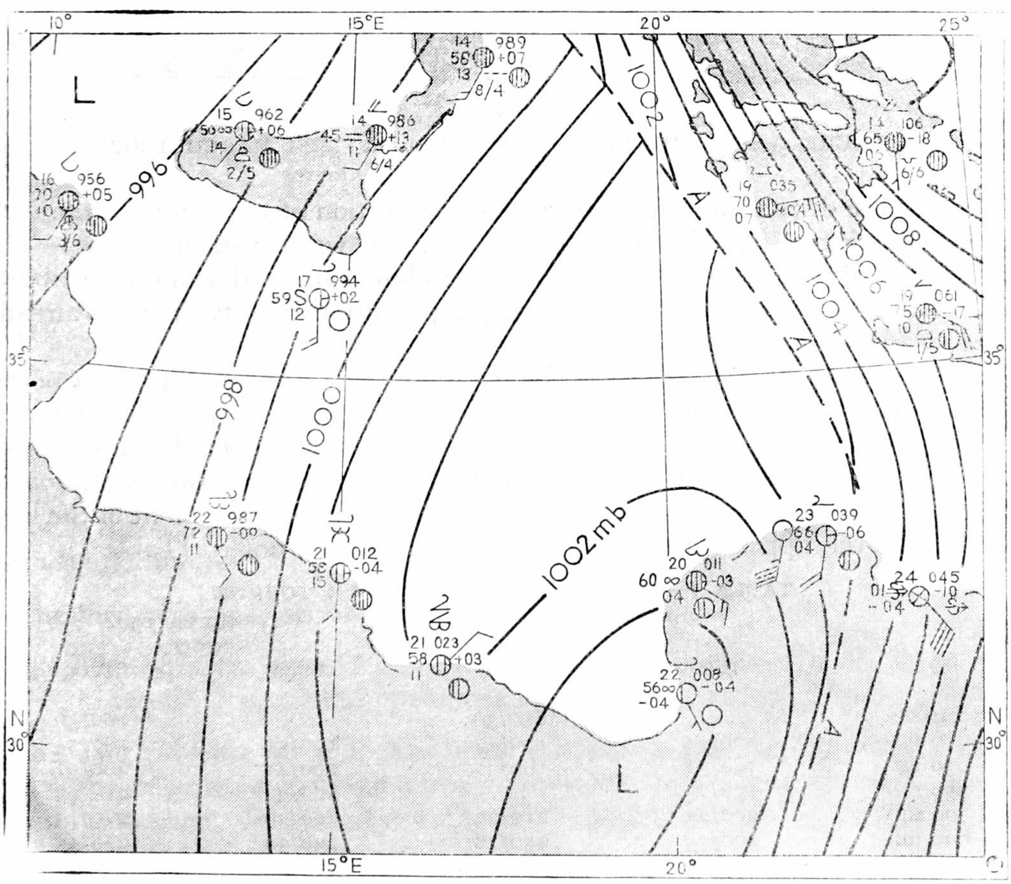


FIGURE 8—SURFACE CHART FOR 0900 GMT, 21 MARCH 1962

20th (Figure 9) and 0001 GMT on the 21st (Figure 10). The rapid transference of the trough over western Tripolitania eastwards to eastern Tripolitania is immediately evident. The isotherms as drawn in Figure 10, copied directly from the working chart, show the existence of an 'advection discontinuity' (i.e. a discontinuity in the thermal advection field) at or near the trough line.

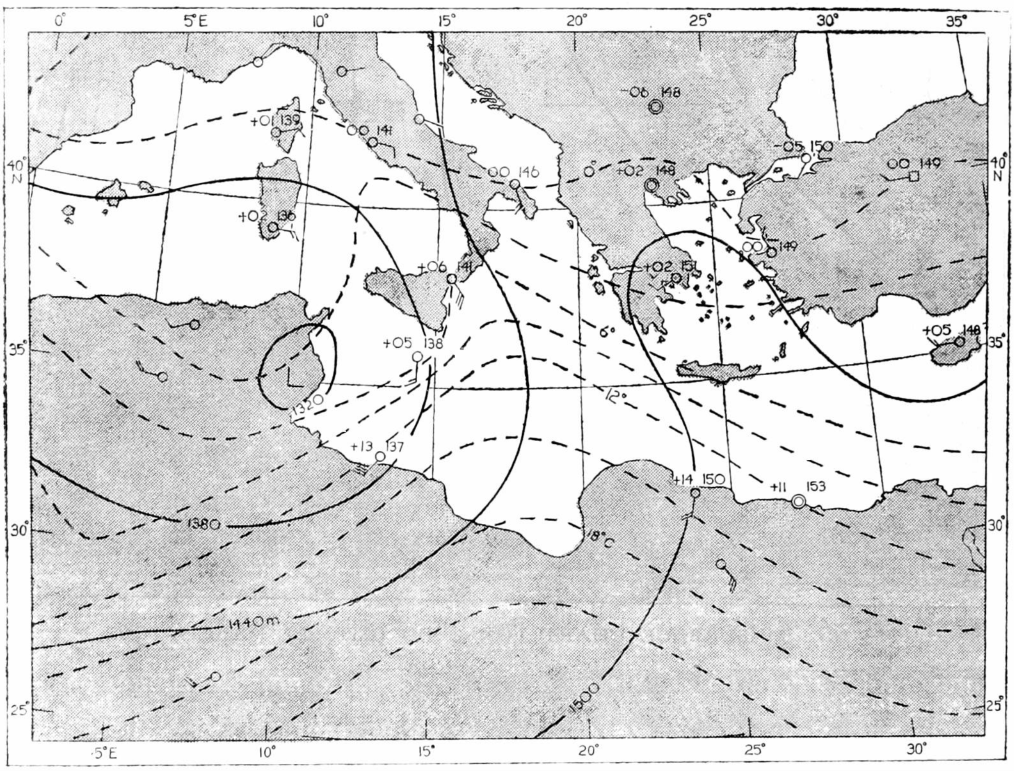


FIGURE 9—850 MB CHART FOR 1200 GMT, 20 MARCH 1962
——— contours, – – – – isotherms

Ahead of the discontinuity there is a strong advection of warm air maintaining a thermal ridge; behind it the pattern is one of weak cold advection. The occurrence of a warm ridge ahead of a trough line is suggestive of the instability line[6] and the association of the 'pressure jump' with instability lines has already been demonstrated by Tepper.[4]

As for the origin of the pressure jumps there are two possibilities not necessarily independent. They may be due to the acceleration and sharpening of the trough at the 850 mb. level. On the other hand Tepper[7] has also shown the possibility of pressure jumps resulting from the impulsive addition of momentum to a southerly flow. In this connexion the development of the low-level jet in the upper wind values for Tobruk may be noted, (Table I).

TABLE I—UPPER WIND VALUES FOR TOBRUK

	20 March 1962 GMT		21 March 1962 GMT	
	1800	0001	0600	1200
		degrees/knots		
Surface	...	150/30	...	180/30
900 mb	160/34	170/42	190/51	180/54
850 mb	190/31	180/37	200/41	200/51
750 mb	190/25	...	220/34	210/45
700 mb	200/23	210/29	220/26	210/43
600 mb	200/23	250/28	230/30	220/45

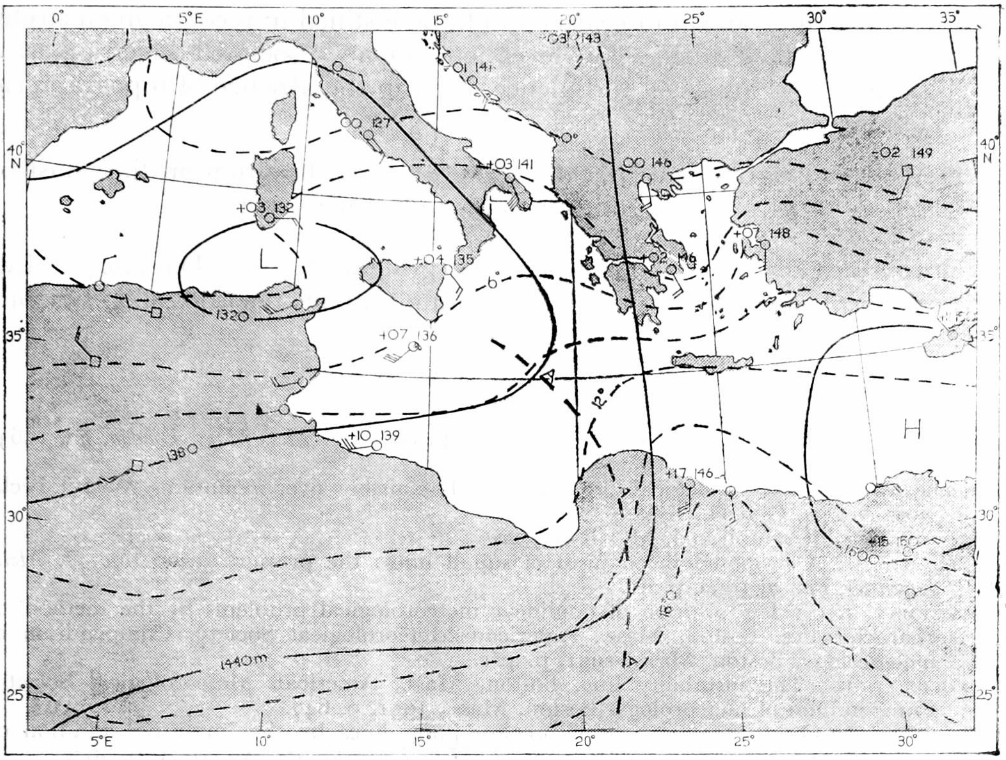


FIGURE 10—850 MB CHART FOR 0001 GMT, 21 MARCH 1962
———— contours, – – – – isotherms
A – – – – *A* advection discontinuity

At Shahat, a high-level station west of Derna, surface winds of over 40 knots from 180° were reported at all synoptic hours between 1500 GMT on the 20th and 0900 GMT on the 21st.

The assertion can now be made that the evidence suggests the association of the turbulence with a line disturbance of the flow. It is known that instability lines are significant for turbulence. Although the associated terms 'instability line' and 'squall line' are almost always used when thunderstorm activity is in evidence, the pressure-jump mechanism is itself independent of precipitation and there appears to be no reason to doubt the relevance of the pressure jump for low-level turbulence even in clear air.

The extent to which the topography in this instance was a contributory factor is unknown and discussion on this point would be unprofitable without further information.

The foregoing analysis illustrates the following points:

(i) The synoptic method of analysis sometimes can be usefully employed in the investigation of phenomena normally regarded as 'meso-scale'.

(ii) The 'pressure jump' line or instability line (a not uncommon feature in the Mediterranean but often unnoticed[8]) has relevance for low-level turbulence, even in clear air.

(iii) The Mediterranean forecaster would be justified in recognizing a strong southerly flow with a low-level jet and an associated inversion as a situation for low-level turbulence, even in the absence of topographical influences.

(iv) Where topographical effects can be expected the situation (iii) must be regarded as highly significant for severe turbulence.

Acknowledgement.— The author is grateful to the Director, Libya Meteorological Service, for providing autographic records and synoptic reports.

REFERENCES

1. GRIMMER, M.; Turbulence near Derna on 21 March 1962. *Met. Mag., London,* **92,** 1963, p. 145.
2. Geneva, World Meteorological Organization. The airflow over mountains. WMO Tech. Note No. 34, Geneva, 1960, p. 22.
3. CORBY, G. A.; Unpublished. MO(R)637(20).
4. TEPPER, M.; A proposed mechanism of squall lines: the pressure jump line. *J. Met., Lancaster, Pa.,* **7,** 1950, p. 21.
5. FREEMAN, J. C.; The solution of nonlinear meteorological problems by the method of characteristics. Boston, Mass., American Meteorological Society. Compendium of meteorology. Boston, Mass., 1951, p. 421.
6. FULKS, J. R.; The instability line. Boston, Mass., American Meteorological Society. Compendium of meteorology. Boston, Mass., 1951, p. 647.
7. TEPPER, M.; On the generation of pressure-jump lines by the impulsive addition of momentum to simple current systems. *J. Met., Lancaster, Pa.,* **12,** 1955, p. 287.
8. KIRK, T. H.; "Pressure jumps" at Malta. *Met. Mag., London,* **90,** 1961, p. 206.

551.501.45:551.573

ESTIMATES OF THE POTENTIAL TRANSPIRATION IN THE MONTH OF MARCH FOR TWO PLACES IN SCOTLAND

By R. W. GLOYNE and N. M. McSWEEN

Introduction.—There is considerable interest, especially in the drier parts of Scotland, in the likelihood of soil moisture deficits in the month of March. However, the simple method of estimating potential transpiration (by a linear regression on sunshine) is not valid in the 'winter' half year (October–March), whilst the data necessary for a full computation by Penman's method require more extensive instrumentation than is available at most climatological stations. Accordingly, an alternative approach is needed, and in this note the relationships between estimated potential transpiration given by the complete calculation and that given by the 'aerodynamic' term, are presented for two places in Scotland.

The argument adopted in an earlier paper by Penman[1] has recently been substantially modified.[2] The earlier paper forms the basis of estimates given in two publications of the Ministry of Agriculture, Fisheries and Food.[3,4] Briefly he allows for the 25 per cent reflection of short-wave solar and sky radiation from a green crop surface by applying a factor of 0.75 to that incident upon such a surface, but omits all reference to the seasonal constant f (< 1.0), previously used to convert evaporation from an open water surface to potential transpiration losses from the crop. The opportunity has been taken to examine the effects of these changes in specific cases.

The several expressions for two stations in Scotland, namely Tiree and Leuchars (Fife), for the month of March were computed thus:

E_{T1} = potential transpiration according to the earlier (1948) formulation (Penman[1]),
E_{T2} = potential transpiration according to the recent (1962) formulation (Penman[2]),
E_a = the 'aerodynamic' term (common to both formulations) where
$E_a = 0.35\ (1 + \bar{u} \times 10^{-2})\ [e_a - e_d]$ mm of water/day,
and $\bar{u}$ = mean run of wind in miles per day at six feet over a grass surface,
e_a = saturation vapour pressure (in mm of mercury) corresponding to the mean air temperature, and
e_d = vapour pressure corresponding to the mean dew-point.

Results.—As is customary, all quantities were converted into inches of water per month. The results are for the month of March and based upon values for the period 1930–62 inclusive.

Leuchars

$E_{T2} = 1.24\ E_{T1} - 0.13$ $\quad \bar{E}_{T2} = 1.06$ $\quad \bar{E}_{T1} = 0.96$
$E_{T2} = 0.43\ E_a + 0.38$ $\quad \bar{E}_a = 1.58$

Tiree

$E_{T2} = 1.40\ E_{T1} - 0.30$ $\quad \bar{E}_{T2} = 1.28$ $\quad \bar{E}_{T1} = 1.12$
$E_{T2} = 0.48\ E_a + 0.33$ $\quad \bar{E}_a = 1.98$

(bars over the symbols indicate mean values).

In each case, the regressions account for over 95 per cent of the total variance.

Discussion.—Although the regression coefficients in the E_{T2} and E_{T1} equations are relatively large, in absolute terms the resulting differences rarely exceed 0.2 inches per month and may be considered insignificant. The exceptional cases, which relate to Tiree, are:

March 1938	E_{T1} = 1.62 in.	E_{T2} = 2.04 in.
March 1958	E_{T1} = 1.70 in.	E_{T2} = 2.11 in.

On these occasions, both the wind speed and the vapour pressure deficit (and hence E_a) were amongst the highest values for the whole series.

A comparison for a shorter (1930–47) series for the month of May at Leuchars gave:

$E_{T2} = 1.10\ E_{T1} - 0.30$ $\quad \bar{E}_{T2} = 2.71$ in. $\quad \bar{E}_{T1} = 2.73$ in.

and again, in absolute terms, the estimates agree closely. However, the scatter is rather greater than for March results.

With respect to estimates for the month of March in southern Scotland, the analysis indicates that:

(*a*) The alterations in the basis of Penman's formulation lead to only small *absolute* differences.

(*b*) The 'aerodynamic' formula allows a good approximation to estimates of potential transpiration arrived at using more complicated procedures.

In connexion with statement (*a*), Grindley[5] notes that some provisional results for southern England also show small absolute differences. However, there are indications that the pattern of seasonal differences over Great Britain as a whole may not be uniform.

REFERENCES

1. PENMAN, H. L.; Natural evaporation from open water, bare soil and grass. *Proc. roy. Soc., London*, A. **193**, 1948, p. 120.
2. PENMAN, H. L.; Woburn irrigation 1951–59. Part 1. *J. agric. Sci., London*, **58**, 1962, p. 343.
3. London, Ministry of Agriculture, Fisheries and Food; The calculation of irrigation need. London, 1954, Technical Bulletin No. 4.
4. London, Ministry of Agriculture, Fisheries and Food; Irrigation. (3rd edn.) London, 1962, Bulletin 138.
5. GRINDLEY, J. ; Private communication, 1962.

551.558.1:551.558.21:629.135.15

GLIDER OBSERVATIONS OF LEE WAVES IN AND ABOVE A FIELD OF CUMULUS CLOUD

By T. A. M. BRADBURY

The existence of lee waves and active convective currents at the same level, and close together, is probably uncommon over the British Isles. It is usually considered that morning heating inhibits the development of lee waves. An essential requirement for strong lee waves is that there should be marked stability at the levels where the air is disturbed by the mountains.[1] The following observations may be of interest because the lower level of lee-wave flow occurred in the middle of a summer afternoon in a layer where active convective clouds existed.

At 1200 GMT on 22 August 1962 the British Isles were under the influence of an eastward moving ridge which lay between an occluded front over the North Sea, and an advancing warm front west of ocean weather station Juliett (Figure 1). The upper air soundings made at this time at Aughton, Camborne

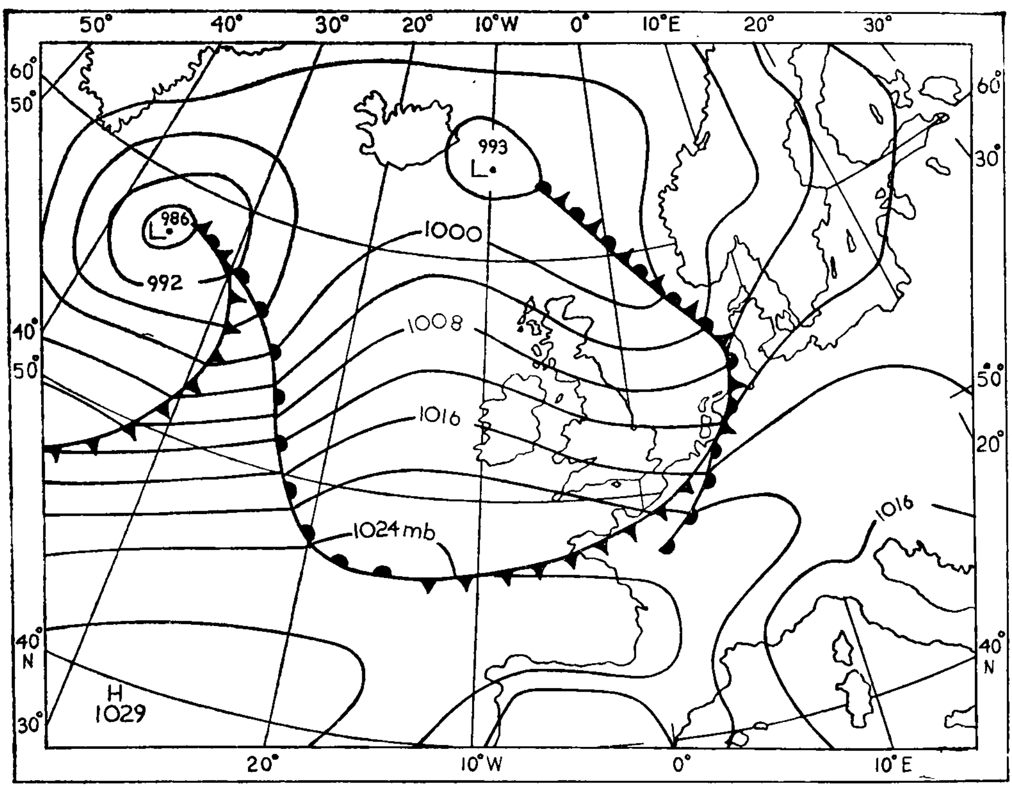


FIGURE 1—SURFACE CHART FOR 1200 GMT, 22 AUGUST 1962

and Valentia all showed an unstable layer at low levels, capped by a stable layer, with reduced stability aloft. In general the level of the stable zone sloped upwards from south to north across England, and lowered to the west over Valentia. The winds aloft were almost constant in direction, increasing with height. The tephigrams for Aughton and Camborne are shown in Figure 2.

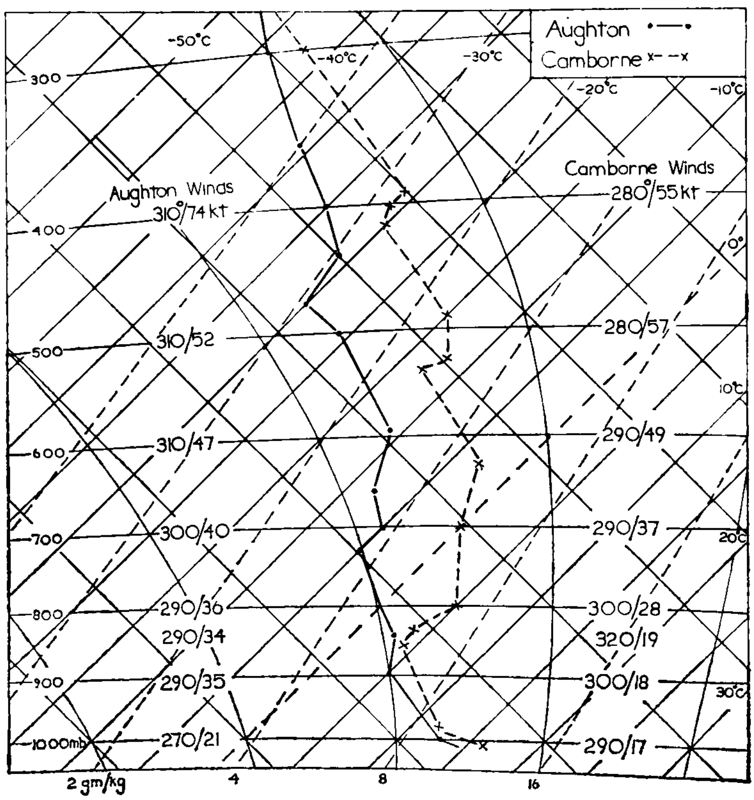


FIGURE 2—TEPHIGRAM FOR AUGHTON AND CAMBORNE, 1200 GMT 22 AUGUST 1962

The glider flight covered the area from Nympsfield (near Stroud), to Ross-on-Wye, Hereford, Bromyard, Tewkesbury and back to Nympsfield, during the period 1250 to 1725 GMT. The machine was a standard class (15 metre span) glider of the type Slingsby Skylark II, fitted with a sensitive electric variometer and carrying a recording barograph. The heights recorded were taken from the barograph trace.

Visual observations between 1300 and 1400 GMT showed active cumulus clouds extending up to 7500 feet above mean sea level over the Cotswolds and to 7000 feet west of the River Severn, with some cumulus streets of a few miles in length lying along the wind direction. The first wave was encountered at 1410 GMT near Cinderford over the position 51°50'N, 02°30'W at 5800 feet above mean sea level. The smooth up-current occurred in a region of clear air less than half a mile upwind of an active cumulus street extending up to about 7000 feet. The lower part of the wave flow was therefore some 1200 feet below the cloud top, and presumably the wave trough dipped even further down. Airflow in, and adjacent to, the cumulus street was found to have an upward component of at least eight knots in the active part of the cloud, with a small downward flow just outside and in the extreme edge of the cloud.

The vertical velocity of the air is based on the assumption that the sinking speed of the glider was 1.7 knots when flying level at about 40 knots. This assumption is not likely to introduce great errors when flight is in smooth air, but in cumulus cloud, when turning at 30 to 40 degrees of bank the rate of sink is probably nearer 2.5 knots.

Flying into wind at about 40 knots indicated air speed the glider climbed to 9100 feet above mean sea level remaining in clear air throughout. The average rate of ascent of the air was just under 3 knots, less at first, but increasing to a maximum of 4.2 knots between the levels 7200 and 7700 feet. Seen from above, the cloud structure showed no indication of the existence of the wave flow. There was no definite pattern in the distribution of cumulus cells, and individual clouds appeared to be travelling with the wind, so far as could be judged from the movement of cloud shadows on the ground.

The glider passed over at least one moderate sized cumulus cloud when moving upwind to the next wave. This wave was reached at 1441 GMT near Ross-on-Wye, over the position 51°53'N, 02°36'W at a height of 6500 feet, about 500 feet below the tops of surrounding cumulus cloud. It is surprising to note that one cumulus appeared to be under the downflowing part of the wave. The upward velocity of the air in the second wave near Ross was initially about 5 knots, with a mean velocity of 3.9 knots up to 7600 feet; above this level it decreased to less than 2 knots.

A more active region of the wave was presently found along a line running approximately NNE–SSW through the position 51°58'N, 02°37'W. Here the mean upward velocity averaged 3 knots through a band from 8000 to 9900 feet. The maximum altitude was reached near Hereford at 1544 GMT when the barograph recorded 11,700 feet above mean sea level, over the position 52°02'N, 02°38'W. Figure 3 shows a cross-section through Ross-on-Wye. From Hereford decreasing wave lift was followed to a position about 52°10'N, 02°31'W, near Bromyard, where the up-current was lost and not again located.

At this time a thickening sheet of cirrus cloud caused a marked reduction of insolation and the cumulus began to decay. As this process continued some clouds began to be modified by the wave flow aloft. No lenticular shapes were seen to the west, but the axis of the wave crest near Ross-on-Wye became evident along a line (approximately) 51°56'N, 02°33'W to 52°00'N, 02°31'W. Above the lenticular top of this cloud the mean upward velocity found was just under 3 knots between the levels 8300 to 9700 feet, with a maximum of 4.2 knots. At 1610 GMT the up-currents near Ross died away, and there was a corresponding disintegration of the wave-form cloud below.

No wave effects were observed in the original area near Cinderford, but a new system developed downwind. This was marked by a very small wisp of lenticular cloud, which formed at 1630 GMT and developed rapidly into a bar of classical shape. In about ten minutes this cloud extended along the line 51°53'N, 02°18'W to 52°02'N, 02°12'W, lying over the Vale of the Severn, mainly west of the river. The glider penetrated the lower part of this cloud as it was forming and experienced some turbulence inside, but the airflow

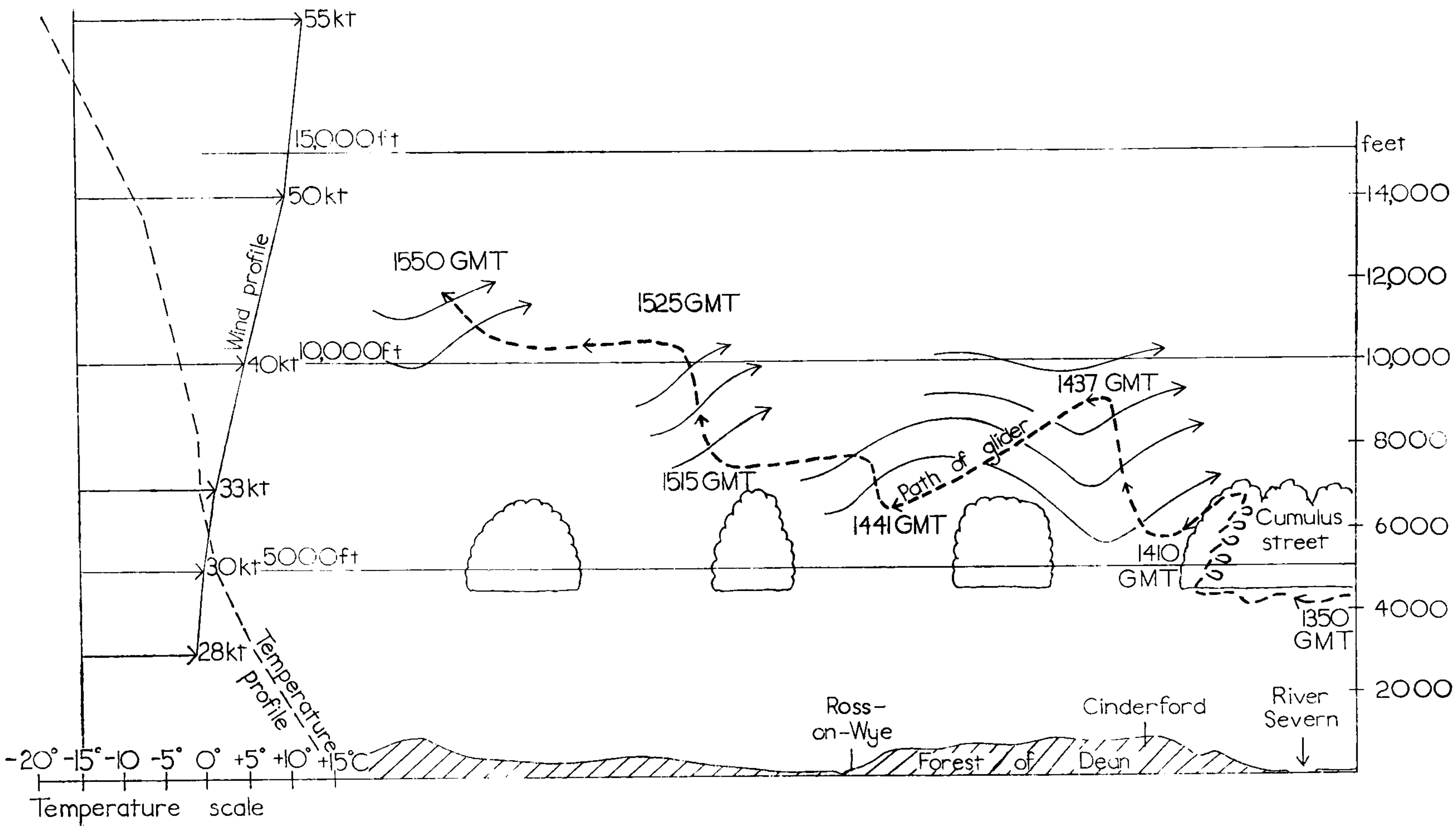


FIGURE 3—NORTH-WEST TO SOUTH-EAST CROSS-SECTION
Showing clouds and suggested airflow 1350–1550 GMT, 22 August 1962 with profiles of wind and temperature.

resumed its characteristic smooth nature at the upwind edge of the cloud, and over the top of it. The maximum observed up-current was just over 5 knots, with an average of 3.4 knots from 6500 to 7700 feet. The fully developed wave flow lasted only about 15 minutes after which the up-current died away and the cloud degenerated into ragged stratocumulus with some turbulence in the lower layers. A final wave cloud was later observed to have formed along the line of the Cotswold edge near Cheltenham, but this wave was not explored. The glider returned to Nympsfield and landed at 1725 GMT. Between 1710 and 1725 the clouds dispersed almost completely, leaving a single bar of lenticular cloud in the direction of Ross-on-Wye, and some smaller clouds near the Malvern hills.

Figure 4 shows the positions of wave lift encountered. An estimate of the conditions over Herefordshire was obtained by interpolating between the values reported from the soundings at Aughton and Camborne. From this interpolation values of Scorer's[2] parameter l^2 were obtained using the lee-wave

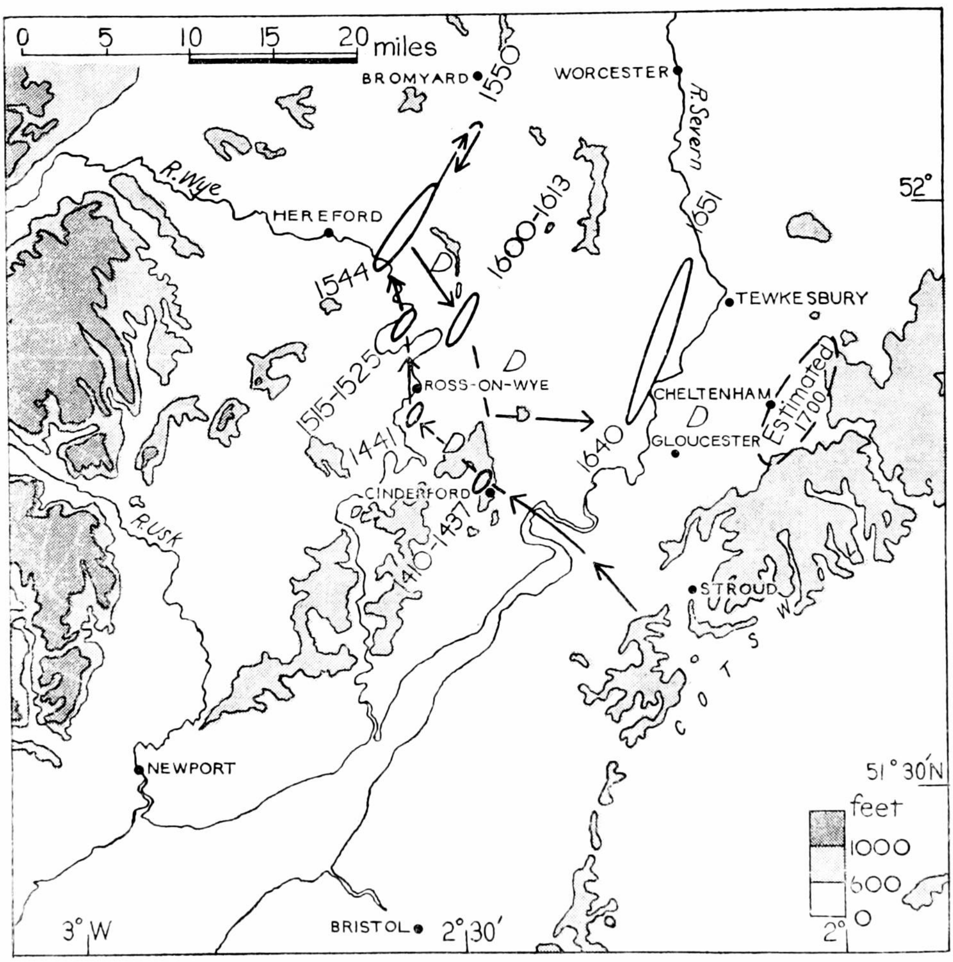


FIGURE 4—LEE-WAVE OBSERVATIONS ON 22 AUGUST 1962

Positions of ascending air outlined and annotated with the duration of the ascent in the up-current. Areas of descending air are marked with a *D*.

scale devised by Wallington.[3] It was found that l^2 increased to a maximum in the layer 790–740 millibars, and then decreased to about one-eighth of this between 610 and 490 millibars. One would expect to find the greatest amplitude of lee waves in the layer 790–740 millibars, and this is borne out by the barograph trace which showed the best rate of climb in the first wave between 7200 and 7700 feet.

It is difficult to suggest any particular mountain slope as the origin of the waves. The Welsh mountains extend some fifty miles upwind of Herefordshire, with peaks of 2000 to 2500 feet. The natural wavelength of the air was probably changing with the approach of the Atlantic warm front (Wallington[4]), and if so it is likely that the wavelength was periodically in phase with the topography. This would account for the apparently irregular wavelength. The most interesting feature however was the existence of lee-wave flow at a level well below the top of the cumulus cloud, and the fact that the waves occurred at a time of maximum convection, when the cumulus tops extended at least 4000 feet above the upwind mountains.

REFERENCES

1. ALAKA, M. A.; The airflow over mountains, WMO Tech. Note No. 34. Geneva, 1960, p. 47.
2. SCORER, R. S.; Theory of waves in the lee of mountains. *Quart. J. R. met. Soc., London,* **75**, 1949, p. 41.
3. WALLINGTON, C. E.; A lee-wave scale. *Quart. J. R. met. Soc., London,* **79**, 1953, p. 545.
4. WALLINGTON, C. E.; Lee waves ahead of a warm front. *Quart, J. R. met. Soc., London,* **81**, 1955, p. 251.

WORKING GROUP ON COLLECTION AND PROCESSING OF MARINE CLIMATOLOGICAL DATA

A session of the World Meteorological Organization (WMO) Working Group on the collection and processing of marine climatological data was held at the WMO Secretariat from 14–18 January 1963, under the chairmanship of the President of the Commission for Marine Meteorology (CMM), Mr. J. A. van Duijnen Montijn of the Netherlands. Members attended from the U.S.A., Netherlands, Norway, United Kingdom, India, Federal Republic of Germany, South Africa and Japan. Mr. F. E. Lumb of the Meteorological Office represented the United Kingdom.

The task of the Working Group was to study the technical and financial aspects of a plan to divide the oceans into areas of responsibility for the collection and processing of marine climatological data. This plan arose from a recommendation of CMM which proposed that the oceans and seas be divided into areas of responsibility, and the main maritime countries (known as Responsible Members) be invited to assume responsibility for one of these areas. For example, the United Kingdom could be responsible for the North Atlantic east of 50°W, and the Mediterranean. Each Responsible Member would collect punched cards (using the International Maritime Meteorological Punch Card which was brought into use as from 1 January 1962), for all ships' observations, of whatever nationality, made in that area. The Responsible Members would also prepare monthly climatological summaries each year for a number of ocean sub-areas, chosen so as to ensure as far as possible a sufficient number of observations to enable useful summaries to be given.

Agreement was reached on a number of items discussed and a draft Resolution embodying the decisions of the Working Group was drawn up for consideration by WMO Fourth Congress.

METEOROLOGICAL OFFICE DISCUSSION

The search for practical solutions in agricultural meteorology

The second Monday Discussion of the winter took place at the Royal Society of Arts on 17 December 1962. Mr. W. H. Hogg opened the discussion with brief descriptions of three widely different types of work with which he had been associated at Bristol, in collaboration with various members of the Ministry of Agriculture, Fisheries and Food. The first dealt with the meteorological aspects of the epidemiology of Black Stem Rust of Wheat. This investigation was based on the use of geostrophic trajectories from surface, 700 mb and 500 mb charts over the period 1947-59 and in general terms it was possible to relate the frequency of trajectories from Spain and Portugal to the severity of the disease in south-west England; the date of observation of the disease was some few weeks after the occurrence of trajectories from these sources. For the period 1955–59 a comparison of trajectories with spore catches showed a close connexion between the catches and trajectories from a southerly or south-easterly direction. In years such as 1955 with an early epidemic, the origin of the spores was probably in Spain or Portugal; in years of later appearance, the inoculum may have originated in France. It was stated that there were difficulties in interpreting results for 1956, when light catches of spores were apparently associated with Atlantic trajectories. A surprisingly close relationship between short-period variations in spore catch in London and trajectory direction over the period 4–10 July 1959 was demonstrated.

The second topic discussed by the opener was based on observations from Rosewarne Experimental Horticulture Station at Camborne and concerned the effects of shelter on the climate. An attempt was made to estimate the geomorphic shelter provided by valleys in a plateau with a general level of about 250 feet. Two years' observations suggested that when all wind directions are considered, the sheltered sites have a run of wind 13–15 per cent below that at the open site; individual directions show greater variability according to position of the sites. A further investigation is now being carried out within an area sheltered by hedges and one of the most interesting points so far noticed is increase of soil temperature during the summer. This may be as much as 2–4°F at 2 inches depth and is still perceptible at 8 inches. In view of these differences it was suggested that a shelter index should take account of factors other than the reduction of wind speed.

The Meteorological Office at Bristol is co-operating in a survey of potential horticultural areas in England and Wales and the methods used in this type of work were outlined. The study is confined to the physical factors of climate, site, soil and water supply, and demands both a general survey of existing information and a field survey. In the meteorological context, the former provides a macroclimatic background which is then confirmed or modified by field assessments of mesoclimate. The general survey is based on standard meteorological data but these are generally of far more value when adapted; for example, the use of degree-days below 60°F can provide a measure of coal needed to produce glasshouse crops, and rainfall and sunshine data are best combined in order to compute water-balance sheets. With regard to frost, the best generalized assessment appears to be one based upon a division of the country into donor and reception areas of cold air, and this is being attempted on 1:25,000 maps.

Field work has involved some reassessment of water needs when soil types are brought under consideration, and frost risk may need to be modified if air movement is impeded by factors not obvious from maps. Some detailed knowledge of the frequency of inversions and their depths during spring would be a great help here. In making field assessments of exposure, some visual aid is provided by wind-pruning of trees and it has sometimes been possible to define areas which are too exposed for horticulture. One of the final aims of the survey is to produce a series of maps showing the areas suitable for horticultural development and a few specimen maps for Devon and Cornwall were shown.

The discussion ranged over a wide field and there were many contributions from visitors interested in agriculture. Dr. Hirst elaborated on some of the aerobiological aspects of spore travel and distribution, and other work being carried out in agrometeorology was referred to, particularly in relation to plant disease and animal comfort. An important practical point which emerged from the discussion concerned the accuracy of meteorological measurements necessary for agricultural work and several speakers agreed that for some purposes a high degree of accuracy was not necessary. The Director-General closed the meeting which had, he said, shown the diversity of interest in the subject of agricultural meteorology.

OFFICIAL PUBLICATION

The following publication, details of which are given on the back cover, has recently been issued: *Weather in the Mediterranean, Volume* 1, (*Second Edition*), London, HMSO, 1962. Price: 84*s*.

LETTER TO THE EDITOR

Hoar-frost crystals

About 1130 this morning (10 February 1963), I noticed on the pavement (the traditional local brick) on two damp patches some large perfect ice crystals. The road which is at about 340 ft is open to the NE and at one spot to north and east. At this point the crystals were of the usual six rayed type, the rays being clear with what appeared to be indented edges and there was an inner ring of six members; diameter about 15 mm. The other crystal further along the pavement was slightly smaller, the rays thicker and feathery, no inner ring. Both cases were on the NW side of the road. There was some thawing going on in places, but some puddles were slightly iced.

5 *Blatchington Road, Tunbridge Wells, Kent.* CICELY M. BOTLEY

[This is a rare observation. W. A. Bentley, "Studies of frost and crystals", *Monthly Weather Review*, XXXV, 1907, p. 352, remarks that hoar-frost crystals of the type concerned rarely or never develop a perfectly symmetrical plan. A. D. Zamarskij in "*Atmospheric Ice*", *Leningrad*, 1955, p. 35, states that hoar-frost crystals of this type, which constituted 20 per cent of those observed at a point in Leningrad in 1945/1947, do not have a pronounced external regularity.

Ed. M.M.]

OBITUARY

Mr. Feliks Kubicki.—It is with deep regret that we record the death, on 25 February 1963 at the age of 47, of Feliks Kubicki, Senior Scientific Assistant. He was injured when his motor cycle was in collision with another vehicle on 26 January and had been in hospital since the accident without recovering consciousness.

Mr. Kubicki came to this country with many of his Polish compatriots in the early days of the last war and served at a number of RAF stations before returning to civilian life in 1947. He came into radiosonde in 1944 receiving his training at Downham Market, was posted to Fazakerley in 1945 and remained a stalwart of that station until it was transferred to Aughton in 1958. His merited promotion to Senior Scientific Assistant came in 1956. Many assistants and some of the Experimental Officer class will remember with gratitude the practical instruction in radiosonde given them by Feliks, for a great number came to Fazakerley and Aughton for their operational training after the preliminary instruction at the Radiosonde Training School. I am sure they, among many others, will wish to extend their heartfelt sympathy to his widow and three children.

It seems an anomaly that there should be a radiosonde station at Aughton without Feliks Kubicki.

Wt 22 K16. 5/63 Gp 1535