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METEOROLOGICAL APPLICATIONS OF CONSTANT-VOLUME BALLOONS

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Introduction.—A previous survey article[1] has attempted to show the usefulness of the constant-level balloon both for operational meteorology and for meteorological research. This earlier article dealt mainly with constant-level balloon (transosonde) flights from Japan at heights of 30,000 and 35,000 feet, the flight at approximately constant level only being realized through the use of a complex and weighty ballast system. More recent constant-level balloon techniques involve the use of a superpressured, constant-volume balloon, thus eliminating the need for ballasting and greatly reducing the weight and cost of the balloon instrumentation. In this article we indicate some meteorological applications of constant-volume balloon flights at relatively low level.

Techniques.—A superpressured, constant-volume balloon maintains nearly constant-level flight without the release of ballast. The reason why this is so can be seen from the equation relating buoyancy force and weight of the balloon system

$$V_b\ (\rho_a - \rho_h) = W \qquad \ldots (1)$$

where V_b is balloon volume, W is system weight, and ρ_a and ρ_h are the densities of air and the inflating gas (hydrogen or helium), respectively. It is seen from equation (1) that if a balloon maintains constant volume it will tend to fly along a surface of constant density. Given a fully inflated non-extensible balloon, the balloon volume could only change owing to seepage of gas through the skin of the balloon or through decrease in temperature of the gas within the balloon either due to radiation or the lowering of the ambient air temperature. However, if initially the gas within the balloon has a considerably greater pressure than the air outside the balloon (superpressure), then in spite of the above processes the non-extensible balloon will maintain its full (and hence constant) volume and possess an equilibrium floating surface for some time.

Constant-volume balloon flights at relatively low level have been made with the so-called tetroons (*tetr*ahedron-shaped ball*oons*). These tetroons are made out of Mylar 1/500 of an inch in thickness, with the Mylar frequently aluminized to provide a radar reflective target. Mylar, being practically non-extensible and possessing high tensile strength and very low permeability, is a highly suitable material for constant-volume balloons and has only recently been developed (the ECHO satellite is made of Mylar). The tetrahedron shape allows the balloon seams to be straight lines, thus increasing the reliability and reducing the cost. Tetroons withstand a superpressure of 100 millibars with only a 1 per cent change in balloon volume.

Trajectories.—Probably the most obvious use for the constant-volume balloon is in the estimation of air trajectories or the trajectories of contaminants. As an example, Figure 1 shows three tetroon trajectories obtained at Yucca Flat, Nevada, within the proving grounds of the Atomic Energy Commission.

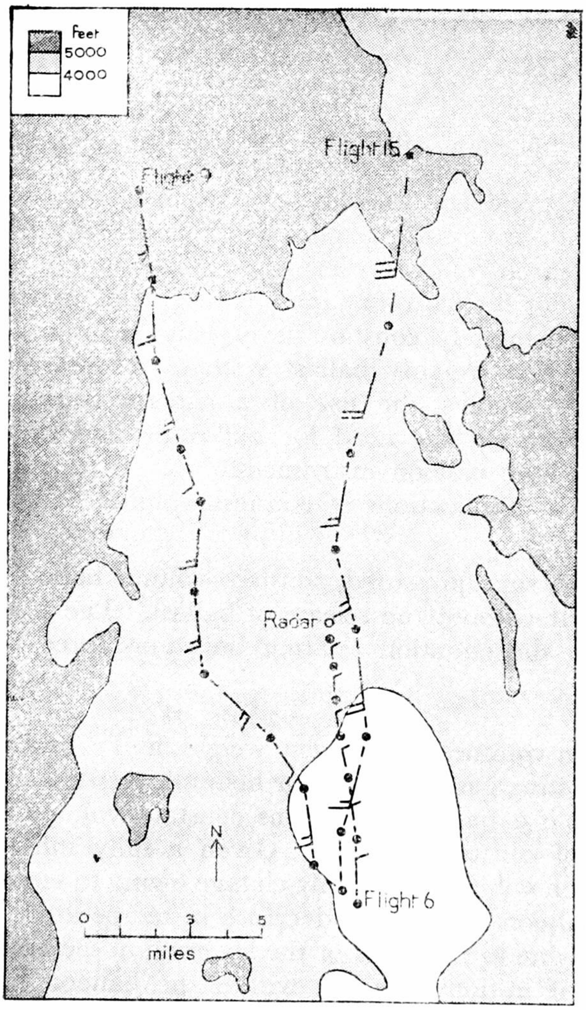

FIGURE 1—TRAJECTORIES OF THREE TETROON FLIGHTS AT YUCCA FLAT, NEVADA PROVING GROUNDS

Tetroon positions and winds at 10-minute intervals

Flight 6 was released at 2000, Flight 15 at 0900, and Flight 9 at 1200 local time, each on different days. As would be anticipated, the trajectories indicate the existance of a strong upslope motion during the day and a weak downslope motion during the night. Also, during the day the trajectories undergo rather large lateral oscillations whereas during the night the trajectories are quite straight. A series of such trajectories has shown a tendency for the air motion to veer with a pendulum day period during the daylight hours within Yucca Flat. The usefulness of such trajectories in delineating areas which would be affected by radio-active material is obvious.

Vertical oscillations.—It has been found that the tetroons are quite easily displaced from their equilibrium density surface. For example, Figure 2 shows the height change as a function of time for the three trajectories presented in Figure 1. The tetroon released in the middle of the day (Flight 9) undergoes height variations of thousands of feet whereas the tetroon released during the

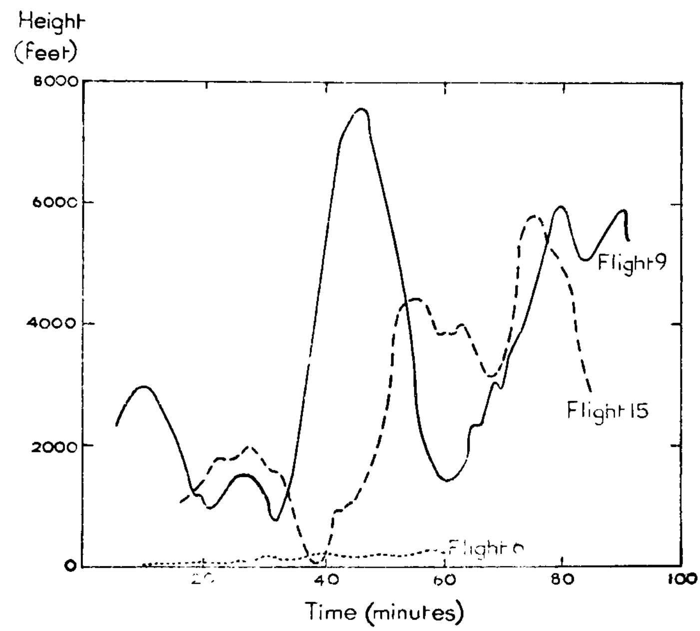

FIGURE 2—TETROON HEIGHT AS A FUNCTION OF TIME FOR THE THREE FLIGHTS OF FIGURE 1

Flight 9 released at 1200, Flight 15 at 0900, Flight 6 at 2000 local time.

evening (Flight 6) undergoes height variations of tens of feet. Data such as these suggest that the tetroon trajectory represents at least a first approximation to the three-dimensional air parcel trajectory. Owing to the tendency for the tetroon to return to its equilibrium surface, however, the tetroon oscillations in the vertical would be expected to be of smaller amplitude than the air parcel oscillations in the vertical. As a matter of interest, during midday flights in Yucca Flat, the vertical tetroon velocity occasionally exceeded the horizontal velocity.

In order further to examine the relationship between tetroon trajectory and air parcel trajectory, the predominant period of tetroon oscillation in the vertical was compared with the period theoretically to be expected for air parcels,[2] that is

$$\tau = 2\pi \left[\frac{T_0}{g\,(\gamma_p - \gamma)}\right]^{\frac{1}{2}}, \qquad \ldots (2)$$

where τ is the period of vertical oscillation, T_0 is the ambient air temperature, g is the acceleration due to gravity, γ_p is the process lapse rate (usually assumed dry adiabatic), and γ is the lapse rate. In Figure 3 this predominant period of tetroon oscillation in the vertical (as determined from spectral analysis) has been plotted as a function of lapse rate. The unstarred numbers represent tetroon flights from Yucca Flat in Nevada, the starred numbers

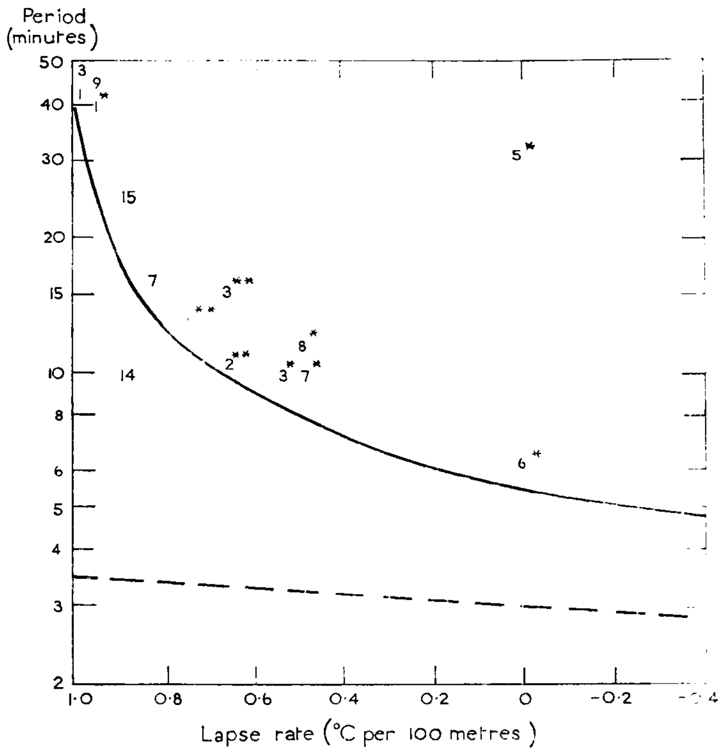

FIGURE 3—THEORETICAL PERIOD OF VERTICAL OSCILLATION OF AIR PARCELS (SOLID LINE) AND CONSTANT-VOLUME BALLOONS (DASHED LINE) AS A FUNCTION OF LAPSE RATE

The plotted numbers show the predominant period of vertical oscillation (spectral peak) along individual tetroon flights.

flights from Wallops Island over the Atlantic Ocean, and the double-starred numbers flights from Easthampstead and Cardington in England. On the two longest tetroon flights (Flights 1* and 3*) it is believed refractive effects at extreme distances have introduced fictitious high-frequency oscillations in the vertical, and consequently for these flights the periods corresponding to secondary lower-frequency spectral peaks have been entered in the figure. It would appear from Figure 3 that the predominant period of tetroon oscillation in the vertical is much nearer to that derived theoretically for an air parcel (solid line) than for a constant-volume balloon (dashed line). Thus this figure, as well as presenting evidence that vertical oscillations with a basis in theory do occur in the atmosphere, suggests that the tetroons tend to follow the vertical air motions rather than undergoing vertical oscillations associated with their own buoyancy.

Two anomalies in Figure 3 are Flights 5* and 14. Flight 5* is of interest in that it was released during the passage of a weak cold front over Wallops Island.

Flight 6* was released 20 minutes later but was tracked by a somewhat inferior radar. However, the positioning of Flight 6* was sufficiently accurate to show that the tetroon underwent vertical oscillations similar to those found along Flight 5* but displaced about two miles downstream. Data derived from these two flights permitted estimation of the speed and direction of travel of the vertical motion pattern traversed by the two flights[3] (about five knots in the general direction of the tetroon trajectories), and hence allowed for the determination of the streamline pattern along both flights as shown in Figure 4.

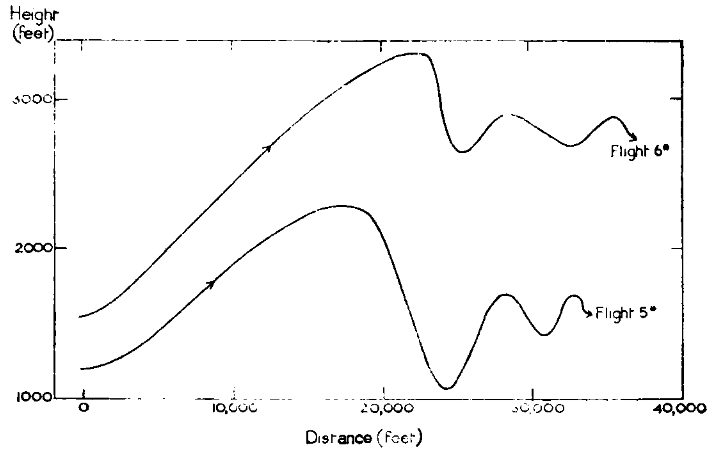

FIGURE 4—SMOOTHED STREAMLINES DERIVED FROM THE TRAJECTORIES OF OVER-WATER TETROON FLIGHTS 5* AND 6*

Note that the vertical scale is exaggerated 10 times with respect to the horizontal scale.

The difference in streamline structure indicated in Figure 4 could be due to the small difference in time of the flights or to their difference in altitude. These vertical motion patterns were moving nearly at right-angles to the frontal intersection with the ground and approximately in the direction of the vertical wind shear through the front. Thus they may well be associated with undulations in the frontal surface occasioned by vertical wind shear. If this is so, then it is not surprising that the predominant periodicity of vertical oscillations along Flight 5* is not solely a function of stability, as apparently is the case with many of the flights plotted in Figure 3.

Tetroons appear as logical instruments to investigate mountain-induced vertical air motions, especially when one considers the interesting results obtained by Gerbier and Berenger[4] using zero-lift balloons. Originally it was hoped that tetroon flights from Yucca Flat could serve as the basis for such an investigation. However, the vertical oscillations during the day due to solar heating were so large (Figure 2) that they masked any vertical oscillations due to topography, while the tetroon flights during evening and early morning were usually confined to Yucca Flat itself. Only Flight 14, which was towed aloft by a radiosonde balloon, fulfilled the criterion of a flight traversing mountainous terrain during a time of negligible solar heating. This flight passed over mountain ridges spaced at approximately four-mile intervals. Figure 5 shows the vertical oscillations of the tetroon with respect to a schematic mountain ridge similar in dimension to the actual mountain ridges. The dotted

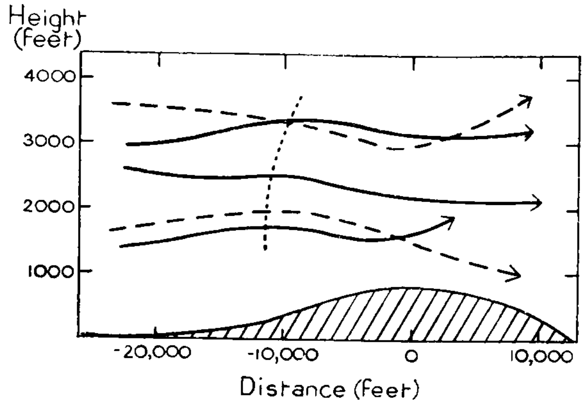

FIGURE 5—SEGMENTS OF THE TRAJECTORY OF TETROON FLIGHT 14 (SOLID LINES) IN RELATION TO (SCHEMATIC) MOUNTAIN RIDGES

The dashed lines are streamlines deduced theoretically by Queney for a medium-sized mountain. Dotted line is locus of maximum tetroon heights.

line connecting points of maximum tetroon height shows that this height was attained almost two miles upstream from the mountain crests and hence the tetroon oscillations were nearly out of phase with the variations in ground height. The trajectories agree only vaguely with the streamlines (dashed lines) deduced theoretically for a medium-sized mountain by Queney.[5] Nevertheless, it is not unreasonable to state that the mountain ridges were inducing tetroon oscillations in the vertical, and with a tetroon velocity of 24 knots and the given ridge spacing, this would yield the vertical oscillations of about ten-minute period found along this flight (Figure 3). A periodicity of nine to ten minutes in the lateral velocity component along Flight 14 suggests that this component was also influenced by the mountains.

Helical circulations.—Most of the day-time tetroon flights over Yucca Flat gave evidence for the existence of helical circulations, although in many cases the flights were too short for a really satisfactory demonstration. Figure 6(*a*) illustrates this helical tendency along Flight 9 (see also Figures 1 and 2).

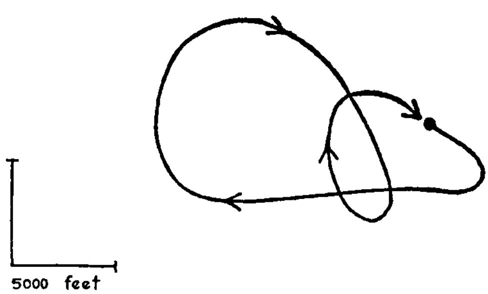

FIGURE 6(*a*)—CIRCULATIONS IN THE TRANSVERSE PLANE ALONG FLIGHT 9

The sense of the helical circulation appeared random when all the day-time flights over Yucca Flat were considered.[6] Of the flights over the sea, however, only Flight 3* exhibited a consistent helical circulation pattern as shown in the somewhat smoothed diagram, Figure 6(*b*). The six circulations in the transverse plane on this 60-minute flight yield a 10-minute periodicity as shown in Figure 3. Note that the helical circulations along Flight 3* are of an order of magnitude smaller than those along Flight 9 and perhaps could only have

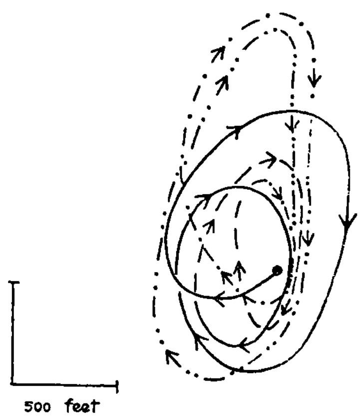

FIGURE 6(b)—CIRCULATIONS IN THE TRANSVERSE PLANE ALONG FLIGHT 3*
Note that the scales on Figures 6(a) and 6(b) differ by an order of magnitude.

been detected through the use of the excellent FPS–16 tracking radar based at Wallops Island. There is no doubt that great care must be exercised in relating these helical tetroon motions to helical air parcel motions since there is always the tendency for the tetroon to return to its equilibrium floating surface. In the case of Flight 9 the large vertical air motions would probably mask any such tendency but this may not be true in the case of Flight 3*. In any event, it is not obvious why helical tetroon circulations existed along over-water Flight 3* when they did not exist under similar stability conditions along over-water Flights 7* and 8*. Insofar as a fairly high wind speed at 3000 feet implies a fairly large wind shear in the vertical, these results could be placed in agreement with model experiments which show that as the vertical shear is increased, the circulation changes from vertical convection (Bénard Cells) to transverse rolls, to longitudinal rolls (helices), to chaotic vertical motion.[7] However, of late there has been some doubt as to the applicability of these model experiments to atmospheric conditions, despite the similarity in results obtained by Woodcock[8] through observations of the soaring of seagulls.

Dispersion estimates.—Dispersion estimates are most naturally made utilizing Lagrangian data, that is, data derived from the trajectories of individual air parcels. Inasmuch as there is evidence that tetroon trajectories approximate to air parcel trajectories, it is reasonable to estimate dispersion directly from tetroon data. It has been shown by Pasquill[9] that after travel time T the crosswind particle variance $\overline{Y^2(T)}$ is given by

$$\overline{Y^2(T)} = \overline{(V_T')}\, T^2, \qquad \ldots (3)$$

where $\overline{(V_T')^2}$ is the crosswind variance of the Lagrangian velocity averaged over T. This equation expresses the intuitively obvious fact that, for short travel times, oscillations of all frequencies contribute to the dispersion whereas for long travel times the low frequency oscillations dominate the dispersion. If Lagrangian data are available, equation (3) appears an extremely easy way of estimating dispersion. There are, however, subtle difficulties involved in the use of even so simple an equation, partly due to the assumptions on which the equation is based and partly to limitations in the data now available to substitute in the equation. These difficulties have been treated elsewhere[10] and it must suffice here to state that the most serious limitation involves the fact that the dispersion should probably not be estimated for travel times exceeding one-tenth the duration of the tetroon flights.

Figure 7 shows the standard deviation of particle displacement in the crosswind direction at downwind distances of 0.5, 1.0 and 2.0 nautical miles as derived from Yucca Flat tetroon flights at varying times of day. These standard deviations were obtained by applying equation (3) to crosswind velocity components derived from radar positionings at one-minute intervals. Worthy of note are the apparent influence of the ground on the dispersion estimated from the lower of the two 0600 flights and the evidence that in the morning,

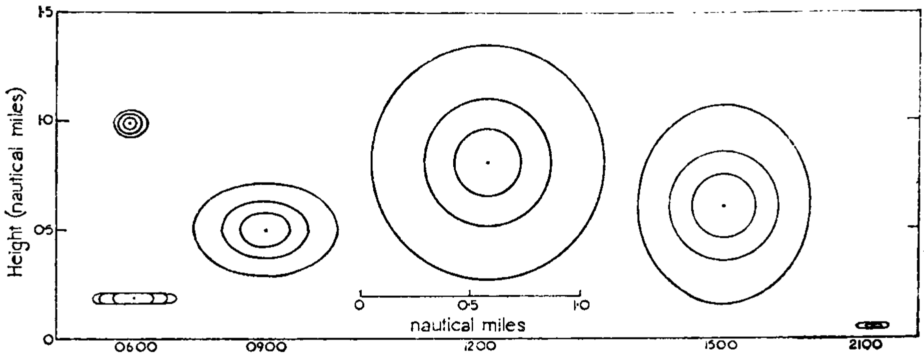

FIGURE 7—STANDARD DEVIATIONS OF VERTICAL AND LATERAL PARTICLE DISPLACEMENT AT DOWNWIND DISTANCES OF 0.5, 1.0 AND 2.0 NAUTICAL MILES (ELLIPSES) AS DERIVED FROM YUCCA FLAT TETROON FLIGHTS AT VARIOUS HEIGHTS AND TIMES OF DAY

when the vertical instability is on the increase, the lateral dispersion is greater than the vertical dispersion, whereas at noon the dispersion in the two directions is equal and in the afternoon the vertical dispersion exceeds the lateral dispersion. Based upon these data, one would estimate the axial concentration of an effluent released at 2100 local time at Yucca Flat to be two to three orders of magnitude greater than the concentration of an effluent released at noon. Thus, in addition to giving the trajectory of an effluent, even a single tetroon trajectory can yield an estimate of the effluent concentration.

In addition to the dispersion from a continuous point source, considerable interest also attaches to relative dispersion or the growth of an individual cluster of particles. Basically, this "smoke-puff" type of dispersion depends upon the increase in distance between pairs of particles and thus is more complex than the continuous point source in that it involves, at the minimum, the obtaining of two trajectories at the same time. Tetroons are just beginning to be used to estimate this type of dispersion but previous attempts along this line have included the use of vertically ascending pilot balloons[11] and zero-lift pilot balloons.[12] The advantage of tetroons over expansible balloons in this type of analysis resides in the fact that the tetroons should better maintain flight altitude and hence the vertical wind shear should not play so great a role in the observed dispersion.

As a preliminary example of the relative dispersion results obtainable from tetroons, Figure 8 shows, as a function of time, the square of the distance separating two simultaneously released tetroons at Cincinnati, Ohio. This trace has been highly smoothed; in fact, the unsmoothed data indicate that at times the tetroons actually moved closer to each other. The smoothed data in

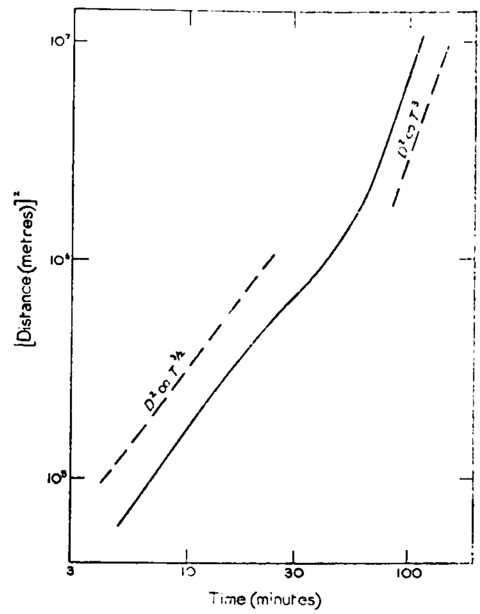

FIGURE 8—SQUARE OF THE DISTANCE BETWEEN TWO SIMULTANEOUSLY RELEASED TETROONS AS A FUNCTION OF TIME

The dashed lines show the power of the time to which the square of the distance is proportional.

Figure 8 show that initially the square of the distance increased approximately as the 3/2 power of the time whereas toward the end of the tracking the increase was near the third power of the time. Overall, the tetroons separated from each other at an average speed of about one knot. Of course, it is impossible to generalize from one experiment, but the results shown in Figure 8 are in general agreement with relative dispersion data on a much smaller scale.[13]

Eulerian–Lagrangian comparisons.—It has been shown above that it is possible to estimate atmospheric dispersion by forming the product of the square of the travel time and the variance of the Lagrangian velocity averaged over the travel time. However, inasmuch as Eulerian (fixed point) statistics are much more easily obtained than Lagrangian (air particle attached) statistics, it is desirable to investigate the possibility of a relationship between these two sets of statistics. Following the fundamental paper of Hay and Pasquill,[14] Eulerian–Lagrangian comparisons near ground level have been made by many people, mainly using the dispersion of fluorescent dye to yield an indirect estimate of the Lagrangian statistic. It has been deduced from these experiments that the period of oscillation in the Lagrangian system exeeds that in the Eulerian system by a factor of about four ($\beta = 4$). At elevations considerably above the ground Eulerian–Lagrangian comparisons are obtained with difficulty. Several years ago Gifford[15] showed the possibility of using zero-lift pilot balloons to estimate the Lagrangian statistics. This method has the disadvantages that the volume (and hence buoyancy force) of the pilot balloon changes in response to heating and cooling and that the pilot balloon has to be released at its equilibrium floating level, making very difficult flights more than a few hundred feet above the ground. The constant volume tetroon with its capability for flight at any height with a ground release appears a more appropriate tool to investigate Eulerian–Lagrangian relationships.

Panofsky and McCormick[16] have shown that if the product of frequency and vertical velocity variance per unit frequency interval is plotted as a function of nz/V (n is frequency, z height above ground, V wind speed), the near-ground Eulerian spectra culled from various sources all exhibit a peak at a value of nz/V between 0.1 and 1.0. They also reproduce a diagram taken from a paper by Lappe, Davidson and Notess[17] showing the mean position of the Eulerian spectral peak of vertical velocity at Brookhaven up to heights of 1600 feet. More recently, F. B. Smith[18] has presented a table giving positions of Eulerian spectral peaks of vertical velocity at Cardington at heights up to 2000 feet. As background material, it is of interest to make comparisons between these data and tetroon data even though the latter were obtained at other places and at other times.

The non-underlined flight numbers in Figure 9 show the predominant periodicity of vertical motion (spectral peak) along individual tetroon flights at functions of flight altitude and nz/V. The solid curve labelled C has been obtained by averaging Smith's Cardington results at heights of 500, 1000, and

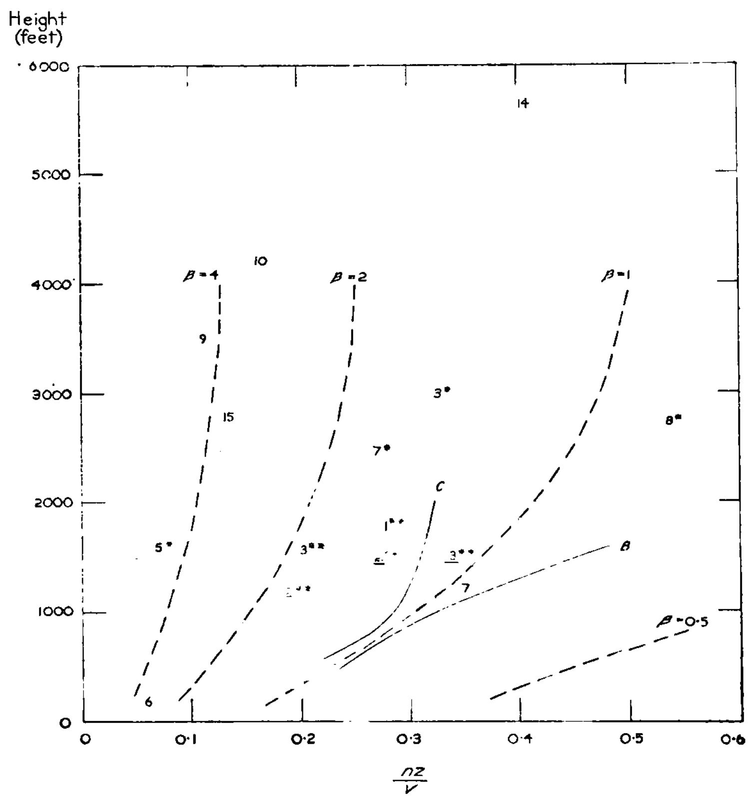

FIGURE 9—PREDOMINANT PERIOD OF TETROON OSCILLATION IN THE VERTICAL (NON-UNDERLINED FLIGHT NUMBERS) AS A FUNCTION OF TETROON HEIGHT AND nz/V, AND MEAN POSITION OF EULERIAN SPECTRAL PEAKS AT CARDINGTON (SOLID LINE C) AND BROOKHAVEN (SOLID LINE B)

Underlined numbers show position of Eulerian spectral peaks at time of tetroon flights.

2000 feet, while the solid curve labelled B is taken from the aforementioned Brookhaven data. As deduced from an interpolation between, and extrapolation of, the Cardington and Brookhaven results, the dashed lines show the values of β for various plottings of tetroon flight numbers. There is, of course, a great danger in comparing Eulerian and Lagrangian data in this way inasmuch as the two kinds of data were obtained in different places at different times.

As an example, from the vertical oscillations along Flights 5* and 6* it has been determined that the tetroons are moving through the vertical motion pattern at the same speed the vertical motion pattern is moving over the ground so that in this case $\beta = 1$. However, in Figure 9, Flight 5* is positioned near the line $\beta = 4$. With these dangers clearly in mind, note from Figure 9 that only Flight 8* falls obviously in the $\beta < 1$ region whereas day-time flights over the desert fall near $\beta = 4$ and flights over the sea generally fall near $\beta = 2$.

At Cardington an attempt is being made to relate Eulerian–Lagrangian statistics by flying tetroons past an instrumented barrage-balloon cable. Only two such direct comparisons are available for presentation here. The underlined numbers 2** and 3** in Figure 9 show the positions of the Eulerian spectral peaks of vertical velocity for the times tetroon Flights 2** and 3** were aloft. The positions of these Eulerian spectral peaks agree well with the mean positions determined from Smith's data. From the relative positions of the Eulerian and Lagrangian spectral peaks one would estimate that during Flight 2** $\beta = 1.5$ and during Flight 3** $\beta = 1.7$. The respective turbulence intensities in the vertical were 0.20 and 0.10. It must be admitted, however, that the Lagrangian spectral peaks were ill-defined on these two flights and consequently these preliminary results should not be taken too literally.

Conclusion.—The evidence that a constant-volume balloon trajectory represents an approximation to a three-dimensional air parcel trajectory suggests the use of tetroons in many fields of investigation other than those mentioned herein. Future studies will include tetroon flights in the Los Angeles Basin for the purpose of delineating trajectories of pollutants and flights within severe storm areas for the purpose of better determining the vertical air motions. Tetroons would also appear logical instruments with which to investigate mountain waves but as yet no specific programme is in mind. There is every reason to believe that the value of the constant-volume balloon will become more and more obvious as time goes on.

REFERENCES

1. ANGELL, J. K.; Use of constant level balloons in meteorology. *Advances in Geophys., New York*, **8**, 1961, p. 137.
2. HOLMBOE, J., FORSYTHE, G. E., and GUSTIN, W.; Dynamic meteorology. John Wiley, New York, 1945, p. 132.
3. ANGELL, J. K. and PACK, D. H.; Analysis of low-level constant volume balloon (tetroon) flights from Wallops Island. *J. Atmos. Sci., Lancaster, Pa.*, **19**, 1962, p. 87.
4. GERBIER, N. and BERENGER, M.; Experimental studies of lee waves in the French Alps. *Quart. J. R. met. Soc., London*, **87**, 1961, p. 13.
5. QUENEY, P.; The problem of air flow over mountains: A summary of theoretical studies. *Bull. Amer. met. Soc., Lancaster, Pa.*, **29**, 1948, p. 16.
6. ANGELL, J. K. and PACK, D. H.; Estimation of vertical air motions in desert terrain from tetroon flights. *Mon. Weath. Rev., Washington, D.C.*, **89**, 1961, p. 273.
7. BRUNT, D.; Experimental cloud formation. Compendium of meteorology, Amer., met. Soc., Boston, Mass., 1951, p. 1255.
8. WOODCOCK, A. H.; Convection and soaring over the open sea. *J. Mar. Res., New Haven, Conn.*, **3**, 1940, p. 248.
9. PASQUILL, F.; Atmospheric diffusion. Van Nostrand, New York, 1961, p. 100.
10. ANGELL, J. K.; On the use of tetroons for the estimation of atmospheric dispersion on the mesoscale. *Mon. Weath. Rev., Washington, D.C.*, **90**, 1962, p.263.
11. BRIER, G. W.; The statistical theory of turbulence and the problem of diffusion in the atmosphere. *J. Met., Lancaster, Pa.*, **7**, 1950, p. 283.
12. WILKINS, E. M.; Observations on the separations of pairs of neutral balloons and applications to atmospheric diffusion theory. *J. Met., Lancaster, Pa.*, **15**, 1958, p. 324.

13. GIFFORD, F.; Relative atmospheric diffusion of smoke puffs. *J. Met., Lancaster, Pa.*, **14**, 1957, p. 410.
14. HAY, J. S. and PASQUILL, F.; Diffusion from a continuous source in relation to the spectrum and scale of turbulence. *Advances in Geophys., New York*, **6**, 1959, p. 345.
15. GIFFORD, F.; A simultaneous Lagrangian–Eulerian turbulence experiment. *Mon. Weath. Rev., Washington, D.C.*, **83**, 1955, p. 293.
16. PANOFSKY, H. A. and MCCORMICK, R. A.; The spectrum of vertical velocity near the surface. *Quart. J. R. met. Soc., London*, **86**, 1960, p. 495.
17. LAPPE, O., DAVIDSON, B. and NOTESS, C. B.; Task Rept. No. 59-517-d, Aer. Bull., U.S. Navy Proj., Washington, D.C., 1959.
18. SMITH, F. B.; An analysis of vertical wind-fluctuations at heights between 500 and 5000 feet. *Quart. J. R. met. Soc., London*, **87**, 1961, p. 180.

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FUMULUS

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The term 'fumulus' has a long history in meteorological literature but, though there has been a revival in its use during the last decade or so, it has no generally accepted definition. The following notes show that over the course of nearly a century, the word which originally described a nascent form of cumulus became associated, probably due to literal or incorrect translation, with smoke and fumes, until, regarded as a popular pseudo-scientific term, it is no longer included in the international classification of cloud forms.

The Annals of the Meteorological Society of France of 1880, contain a paper by Ritter[1] in which he states, with reference to the early stages of cumulus growth, that the 'cloud' first becomes visible as constantly changing and sometimes transient whirls, resembling the capricious movement of light smoke (fumée) and aptly described by the word 'fumulus'. This description of 'fumulus' suggests a fuller understanding of the processes peculiar to the development of fractocumulus than the earlier reference to fractocumulus as "wind-cloud". [2, 3]

For many years, publications mentioned 'fumulus' with reference to Ritter and associated it with fractocumulus. For example, in 1917 a Rome[4] publication so refers to a 'species' — 'fumulus', and the *International Atlas of Clouds* (1932[5] and 1939[6], though not the very brief first edition of 1896[7] or the recent 1956[8] edition) and the *Handbook of Meteorology*[9] give the following description:

"**Fumulus** (*Fum.*)–*Ritter* 1880. At all levels, from Cirrus to Stratus, a very thin veil may form, so delicate that it may be almost invisible. These veils seem to be most frequent on hot days, and in low latitudes. Occasionally they may be observed to thicken rapidly, forming clouds easily visible, especially Cirrus and Cumulus. The clouds thus produced seem unstable, however, and usually melt away soon after their formation.

"Cirrus fumulus must not be confused with Cirrostratus nebulosus. The latter is more stable and does not show the phenomenon of the formation and subsequent rapid disappearance of Cirrus clouds."

[Cirro-nebula is a variety which was first suggested by the Rev. W. Clement Ley[10]: cirrostratus nebulosus is referred to by Abercromby[10] and Clayden[11], and is defined in the *Handbook of Meteorology*[9] as "a very uniform light nebulous veil, sometimes extremely thin, hardly visible and sometimes relatively dense but always without definite details and with halo phenomena".]

The *International Atlas of Clouds*[5, 6] includes, in addition, a plate depicting "Clouds associated with moderate convection" and, in particular, a form of "cloud" in which "condensation is only beginning" and which is "hardly visible"; this "cloud" is referred to as the "fumulus stage" of the (moderately) convective cloud.

In approximate conformity with the main text of the *International Atlas of Clouds*,[5, 6] Perrie[12] refers to fumulus as follows:

"The first cloud produced by thermal updrafts usually takes the form of fractocumulus. Fractocumulus is a ragged cloud, and takes very irregular forms, ... Veils of mist observed to precede the actual formation of these clouds are sometimes known as *fumulus*."

From about 1950, the term 'fumulus' rapidly became very popular in meteorological literature, but was used more diversely. For instance, the term was applied to cloud originating from plumes from chimneys, and Scorer[13] refers to an "unwashed plume rising to cloud base and forming 'fumulus' bubbles". His diagram shows outlines of visible matter partly above and partly below lines representing the general cloud (condensation) levels. This definition implies that 'fumulus' is primarily water cloud of cumuliform type and, in this instance, above a mass of smoke in which there is either practically nil or limited condensation (that is, water content less than in ordinary cumulus). A comparable definition is suggested by a photograph[14] published with the caption, "Fumulus: small cumulus clouds formed by a heath fire near Bordon, Hampshire, 17 March". The burning source would itself contribute to the total atmospheric moisture[15] and help to lower the condensation level.

This lowering of condensation level by the addition of moisture is illustrated by observations of ship-made cloud formed with the aid of funnel exhaust:[16] artificial cloud appeared to form either below that of the natural cloud formation[17] or lower than that suggested by surface dry-bulb and dew-point temperatures.[18, 19] The assistance of artificial heat to natural convection is suggested by two such observations: one [20] refers to cloud forming only in the vicinity of existing tufts and the other[18, 21] to the formation of ship cumulus where and when the sea appeared chocolate-coloured and extremely opaque, due to marine organisms. Artificial (water) cloud may form more easily over sea than over land on account of the greater marine tendency for neutral stability with adequate moisture: also, similarity between the speed and direction of movement of ship and atmosphere would help to maintain such cloud (there being little or no wind shear relative to the moving heat source). One ship report[18] refers to the gradual transition from smoke to cumulus: it states that "the exhaust gases rising slowly from the funnel were seen to change gradually from blue-grey to white" (fumulus?) "and after some minutes a small puff of what seemed to be fair weather cumulus formed over the vessel at an estimated height of 100–200 ft. over the sea. Air temp. 70.4° F, dew point 64°. Wind S'W, force 4–5. Ship's course 010° at 16.3 kt."

The current *International Cloud Atlas*[8] contains a section on clouds from fires (describing for example convective, mainly water-droplet cloud from a certain level upwards, bulging up out of smoke cloud) and a plate depicting 'smoke layer cloud' but, however, no reference to fumulus. It is stated therein that "In spite of the similarity of form between such fire clouds and cloud produced by ordinary convection (Cumulus congestus and Cumulonimbus), the former can easily be recognized by the rapidity of their development and by their dark colour". While this may be true of the towering mushroom cloud from an atomic explosion or volcanic eruption, the intensity and direction of illumination and the type of background have considerable effects on cloud appearance (see for example Scorer[22]) and identification is often inferred from the surrounding topography.

Plate I (facing p. 52) shows a mass of cloud centred over the industrial town of Halifax (about 400 feet above mean sea level), looking north-west from a point about 700 feet above mean sea level, at 0930 GMT, 22 December 1957: the weather was generally cloudy, with cirrus and altocumulus and poor visibility; according to the *Daily Weather Report*, Halifax was in a warm sector. Plate II (facing p. 52) shows a similar view at 0935 GMT, 23 August 1958, when visibility was good. The height of the low cloud top was estimated from the photographs to be roughly 1000 feet above ground level. The low cloud was rather dark against the light upper cloud but, on the whole, synoptic and local conditions suggest predominanlty water cloud. The underside of the cloud appears to merge with smoke from the many local sources of pollution (see Plate I) feeding the 'fumulus' (?) from below. The base of the cloud may be associated with the level of maximum concentration of pollution: a local study[23] suggests that there is a level of maximum mean sulphur dioxide concentration at about 900 feet above mean sea level, that is, about 500 feet above central Halifax. Convergence due to artificial heating[24] below the cloud may be reinforced by local convergence due to orography and/or nocturnal cooling of surrounding hills. The latter factors may well have helped to increase stability at the level of the flat cloud top.

A recent book[25] refers to 'fumulus' as a yellow or brown smoke layer cloud (sometimes called high fog), and ascribes this definition to Scorer who, however, repudiates the statement[26] and says that 'fumulus' is essentially cumuliform. Later, a publication[27] of the Meteorological Office compromises with the following description:

"When the unsaturated bubbles can hardly reach the condensation level, their presence in a smoky atmosphere may be shown by the beginnings of condensation, giving misty patches in the same way that mist forms before a smoke fog even though the air is not saturated. These 'fumulus' clouds may grow into normal *Cu.*"

This is consistent with a recommendation made by Scorer in 1962 to use the term 'fumulus' for the dome-shaped masses produced by 'pollution thermals' before the general condensation level (100 per cent humidity) is reached. According to some of the later descriptions, this type of cloud might have been referred to as the 'sub-fumulus': it could, for example, be formed as a result of diurnal heating and turbulence breaking up a thick, polluted, stable layer. When practically no water is present, the resulting globules of dense pollution could be aptly described by the word 'smogulus'; one can thus reserve the word 'fumulus' for clouds with limited water content which precede the final indistinguishable 'water' (or normal) cumulus.

These three categories are clearly illustrated in a photograph[28] of 'a cloud formed on the top of a smoke plume produced by a grass fire' and which is reproduced as Plate III; dark billowing smoke (smogulus?) is merging up into a cloud with bulging light patches of condensation (fumulus?), which in turn merges into a white mass of normal cumulus above. The latter two types occur, in this instance, where the plume spreads out horizontally and probably thereby experiences greater cooling by mixing.

The word 'fumulus' should have a standard definition or be replaced by any suitable ramifications, such as 'cumulofumus' and/or 'cumulosmogus', for useful re-inclusion in the *International Cloud Atlas.*

REFERENCES

1. RITTER, C.; Annuaire de la Société Météorologique de France. Paris, **28**, 1880, p. 109 and facing p. 160.
2. POEY, A.; Comptes-rendus de l'Académie des Sciences de Paris. Paris, **56**, 1863, p. 361.
3. POEY, A.; Nouvelle classification des nuages. Paris, 1873, pp. 38–40.
4. TAFFARA, L.; Le Nubi. R. Ufficio Centrale Di Meteorologia e Geodinamica. Rome, 1917.
5. Paris, International Meteorological Committee, International atlas of clouds and of states of the sky. Paris, **1**, IMC, 1932, p. 24.
6. Paris, International Meteorological Committee, International atlas of clouds and of types of skies. Paris, IMC, 1939, p. 22.
7. HILDEBRANDSSON, H., RIGGENBACH, A. and TEISSERENC DE BORT, L.; International Cloud-atlas. Paris, IMC, 1896, p. 15.
8. Geneva, World Meteorological Organization; International cloud atlas. Geneva, W.M.O., 1956, Vol. 1, p. 58, Vol. 2 plate 203.
9. BERRY, F. A., BOLLAY, E., and BEERS, N. R.; Handbook of Meteorology. McGraw-Hill Book Co., Inc., London, 1945, p. 891, p. 886.
10. ABERCROMBY, R.; Suggestions for an international nomenclature of clouds. *Quart. J. R. met. Soc., London*, **62**, 1887, p. 158.
11. CLAYDEN, A. W.; Cloud studies. London, 1905.
12. PERRIE, D. W.; Cloud physics. New York, 1950, p. 19.
13. SCORER, R. S.; Plumes from tall chimneys. *Weather, London*, **10**, 1955, p. 108.
14. NIMMO, M.; Plate 35. *Weather, London*, **11**, 1956, opposite p. 295.
15. HUMPHREYS, W. J.; Fogs, clouds and aviation. Baltimore, 1943, pp. 92 and 109.
16. LAWRENCE, E. N.; Artificial cloud formation over sea. *Mar. Obs., London*, **33**, 1963, p. 33.
17. s.s. *Himalaya*; Ship-made cumulus. Indian Ocean. *Mar. Obs., London*, **30**, 1960, p. 11.
18. m.v. *Rangitata*; Ship-made cloud. Peruvian waters. *Mar. Obs., London*, **31**, 1961, p. 64.
19. m.v. *Hertford*; Ship-made cumulus. Indian Ocean. *Mar. Obs., London*, **32**, 1962, p. 56.
20. s.s. *Athelstane;* Artificial cloud formation. North Atlantic Ocean. *Mar. Obs., London*, **21**, 1951, p. 79.
21. m.v. *Rangitata;* Discoloured water, Peruvian waters. *Mar. Obs., London,* **31**, 1961, p. 60.
22. SCORER, R. S.; The photography of air pollution. *Proc. Int. Clean Air Conf., London*, 1960, p. 228.
23. LAWRENCE, E. N.; Atmospheric pollution (sulphur dioxide) in hilly terrain. *Int. J. Air and Water Poll.*, **6**, 1962, p. 10.
24. GEIGER, R.; The climate near the ground. Cambridge, Mass., 1950, p. 384.
25. WALLINGTON, C. E.; Meteorology for glider pilots. London, 1961, p. 46.
26. SCORER, R. S.; Review: Meteorology for glider pilots. By C. E. Wallington. *Quart. J. R. met. Soc., London*, **87**, 1961, p. 616.
27. London, Meteorological Office; A course in elementary meteorology. HMSO, London, 1962, p. 78.
28. TURNER, J. S.; The 'starting plume' in neutral surroundings. *J. Fluid Mech., London*, **13**, 1962, opposite p. 368.

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ANALYSIS OF A WEAK DISCONTINUITY AT MALTA, 2 SEPTEMBER 1960

By T. H. KIRK

The problems of analysis and forecasting in the Mediterranean area have received much attention recently. Few examples are available, however, to demonstrate the nature of the difficulties. The occurrence of a weak "discontinuity" at Malta on 2 September 1960 has been selected for illustration, firstly because it demonstrates the necessity for attention to detail and secondly, because it provides some evidence of the significance of the "pressure jump" to which reference has already been made in a previous note.[1]

The day at Malta had been fine with very light winds, mainly between south and east. At about 2000 local time (1900 GMT) the wind became completely calm but between 2300 local time and midnight it shifted to north-west, remaining very light and intermittent (see Figure 1). Cloud during the day

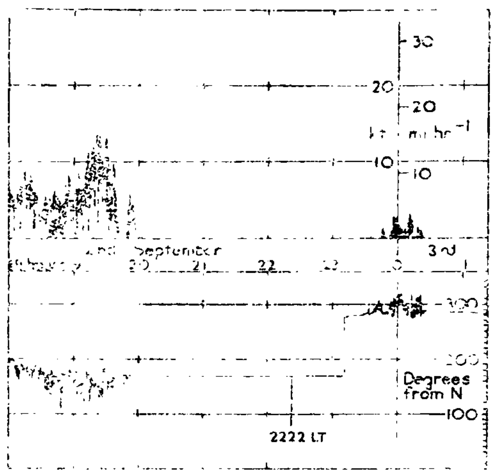


FIGURE 1—SURFACE WIND AT LUQA, 2 SEPTEMBER 1960

had been one to three oktas of unstable altocumulus until 2315 GMT when the occurrence of three oktas of low stratus at 800 ft necessitated the issue of a special report. Patches of stratus persisted throughout the night until 0745 GMT the following day.

Figure 2 shows the barograph trace during the evening. Making the necessary corrections from the time marks it is seen that the main pressure rise was initiated at approximately 1940 local time by a pressure jump which, although small, is nevertheless unmistakable. Its arrival coincided with the sharp fall in wind speed between 1900 and 2000 local time shown on the anemogram. The minor kink in the barograph trace at approximately 2300 local time corresponds with the veering of the wind to north-west. The thermogram (Figure 3) shows a discontinuity of temperature gradient at about 2045 local time followed by a less marked discontinuity at about 2300 local time corresponding with the onset of the north-westerly wind.

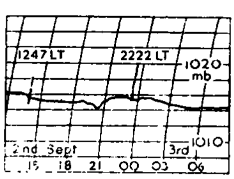


FIGURE 2—BAROGRAM FOR LUQA, 2 SEPTEMBER 1960

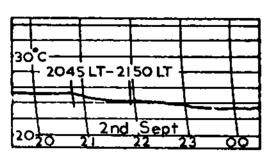


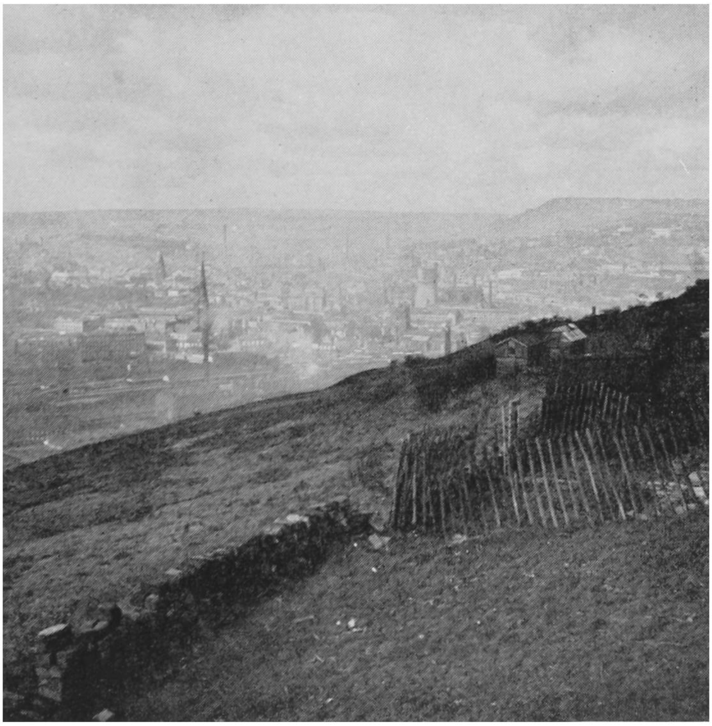
FIGURE 3—THERMOGRAM FOR LUQA, 2 SEPTEMBER 1960

Turning now to the synoptic situation, Figures 4, 5, 6 and 7 show the sequence of events at the surface at 0600, 1200 and 1800 GMT, 2 September and 0001 GMT, 3 September 1960. The large variations in the values of temperature

Photograph by W. Shackleton

PLATE I—VIEW OF HALIFAX, YORKSHIRE, LOOKING NORTH-WEST, 22 DECEMBER 1957

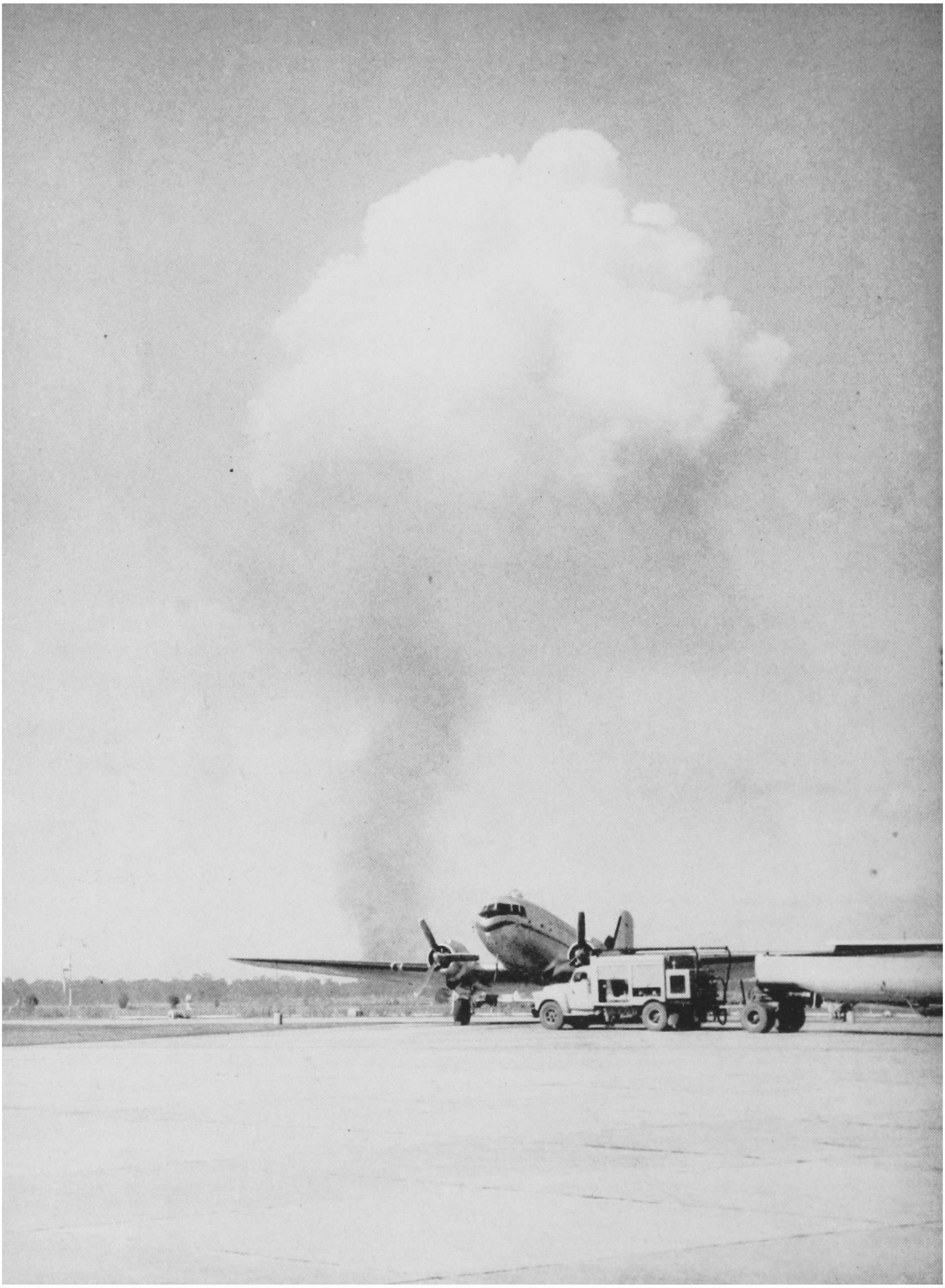
(see p. 50)



Photograph by W. Shackleton

PLATE II—VIEW OF HALIFAX, YORKSHIRE, LOOKING NORTH-WEST, 23 AUGUST 1958

(see p. 50)



Photograph by K. J. Heffernan *Reproduced by courtesy of Journal of Fluid Mechanics*

PLATE III—CLOUD FORMED ON TOP OF A SMOKE PLUME PRODUCED BY A GRASS FIRE

(see p. 50)

PLATE IV—METEOROLOGICAL OFFICE ARCHIVES
(see p. 64)

To face p. 53]

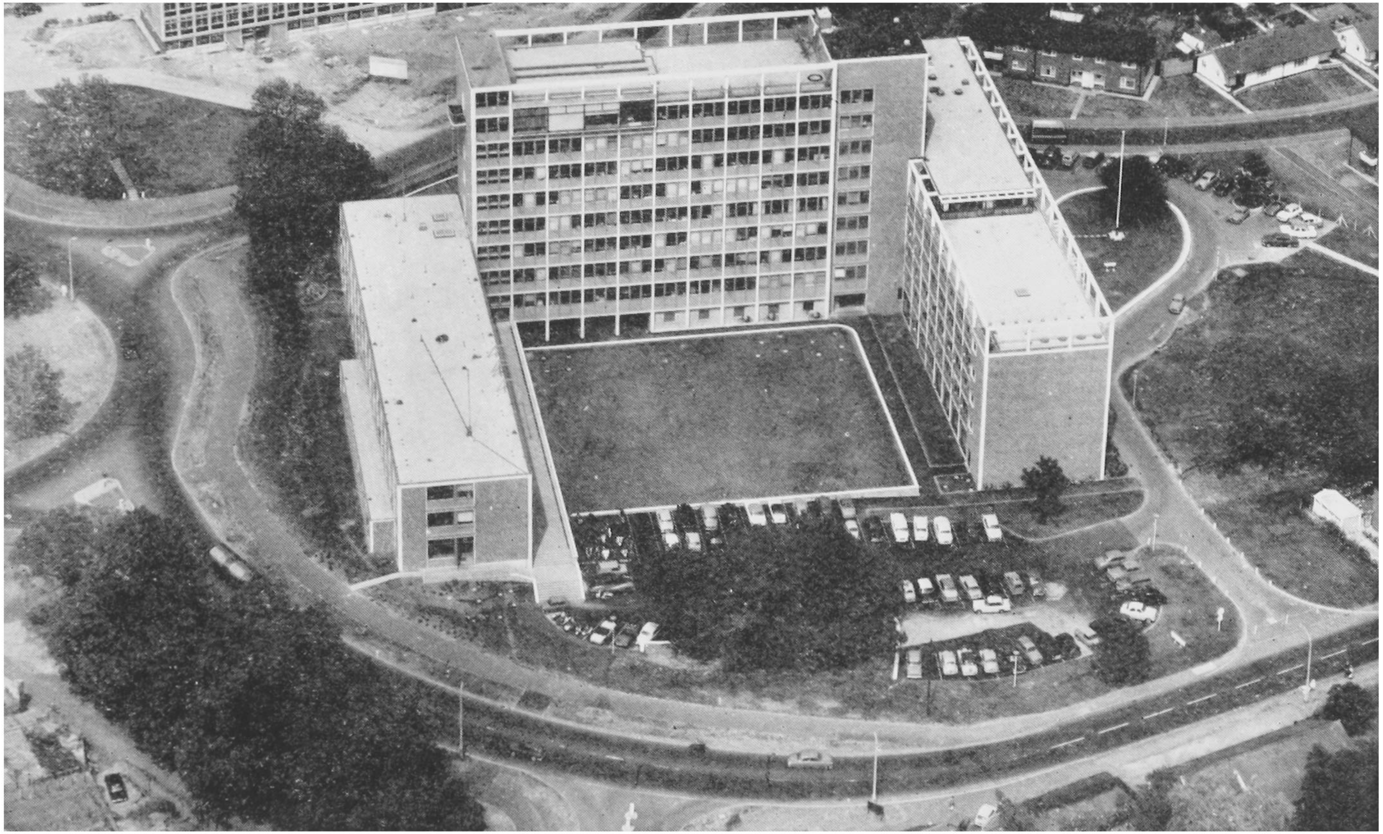


PLATE V—AERIAL VIEW OF THE METEOROLOGICAL OFFICE, BRACKNELL, FROM THE SOUTH-WEST

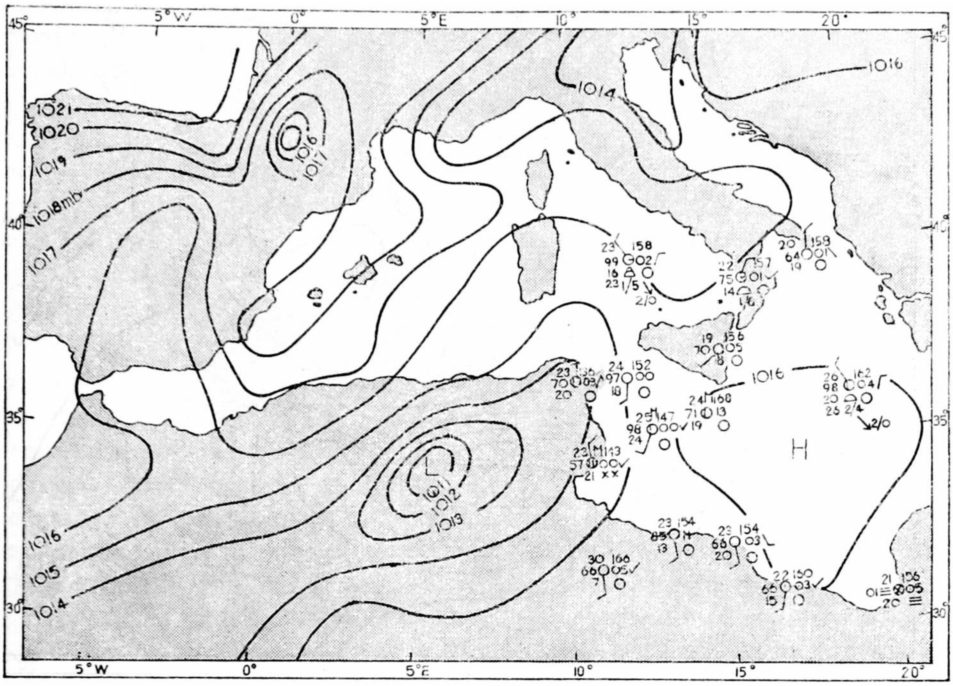


FIGURE 4—SURFACE CHART FOR 0600 GMT, 2 SEPTEMBER 1960

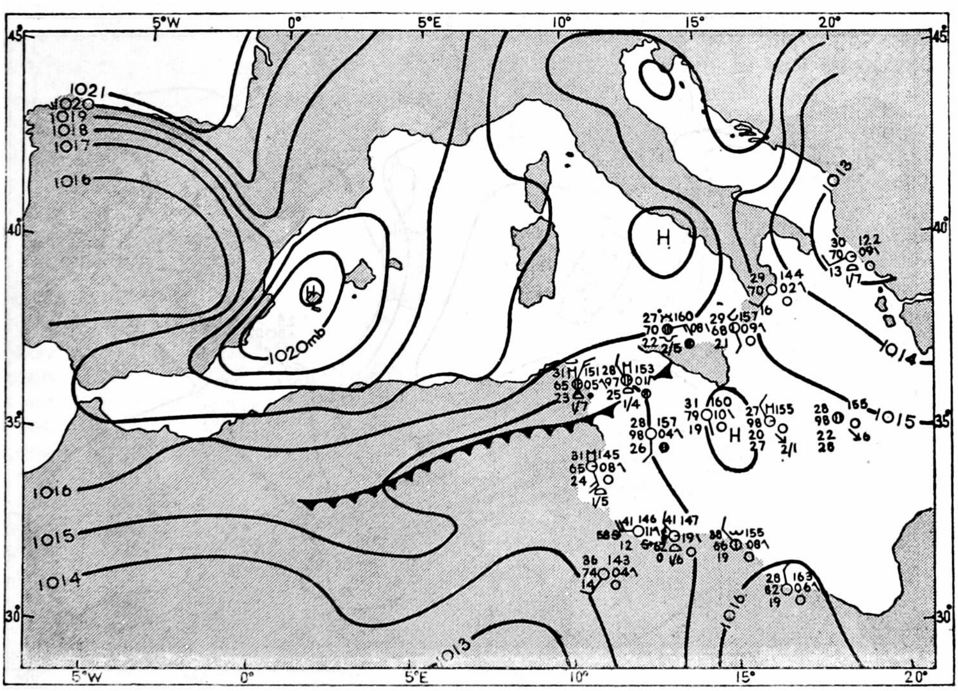


FIGURE 5—SURFACE CHART FOR 1200 GMT, 2 SEPTEMBER 1960

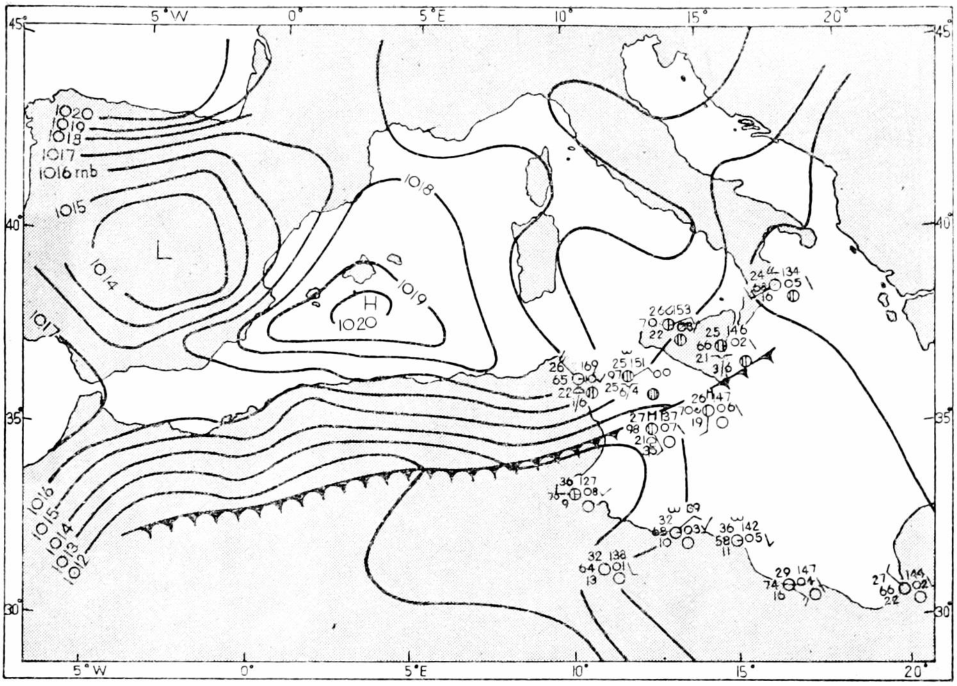


FIGURE 6—SURFACE CHART FOR 1800 GMT, 2 SEPTEMBER 1960

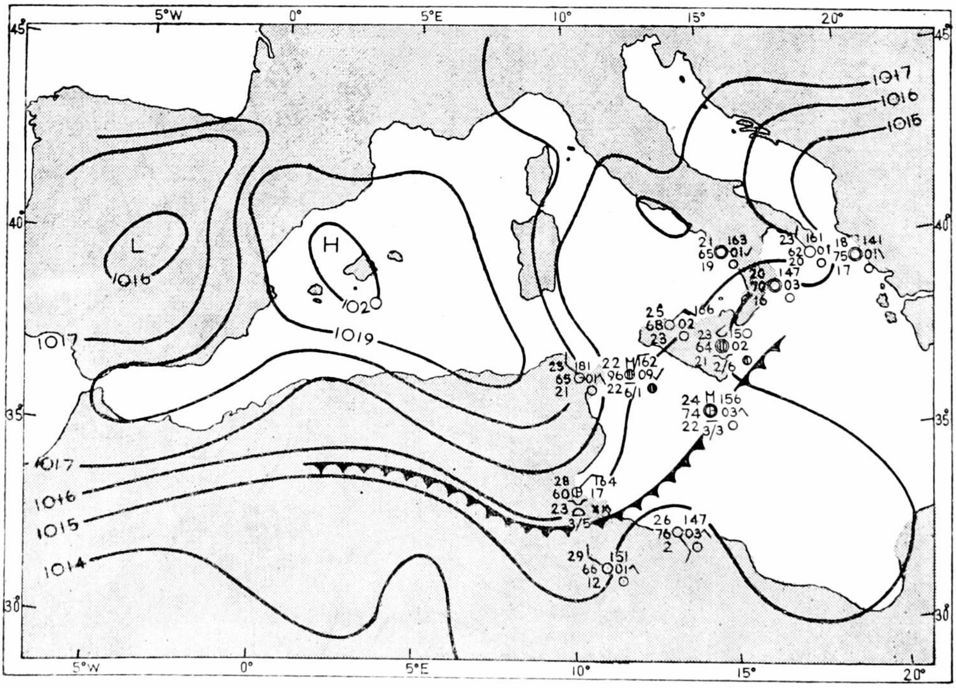


FIGURE 7—SURFACE CHART FOR 0001 GMT, 3 SEPTEMBER 1960

(and dew-point) and wind, combined with the apparent absence of "weather", immediately emphasize the limitations of the surface chart as an aid to the analysis. However, the occurrence of medium cloud of unstable types does suggest instability aloft over Sardinia, the Tyrrhenian Sea and Italy. This is confirmed by the SFLOC reports taken from both the United Kingdom and Mediterranean SFERIC networks and shown in Figures 8, 9 and 10. There is evidently some overlapping in the observations and a probability of position errors but there can be no doubt of the existence of the thunderstorm activity in the areas mentioned. Luqa reported distant lightning flashes to the north-west at 2230 and 2315 GMT. Distant precipitation not reaching the ground was reported to the north-west at 1715, 1745 and 1757 GMT.

Experience has taught the value of the 850 mb chart for depicting conditions near the surface while yet avoiding the complication introduced by many purely local effects. Figures 11, 12, 13 and 14 show the 850 mb charts at 0001 and 1200 GMT on the 2nd and 0001 and 1200 GMT on the 3rd. We recognize at once a weak westerly flow pattern together with isotherms running roughly west to east but with minor wave-like distortions. Although the main temperature gradient is from south to north, it is the minor disturbances moving from west to east in which we are interested. The passage of a very weak discontinuity can be traced at the 850 mb level and it is important to note its close association with the thermal ridge. Behind the discontinuity, the flow was one of cold advection and both thermal trough and ridge slowly increased in amplitude. The temperature at Elmas dropped steadily on the 850 mb charts in the sequence 18°, 16°, 15° and 12°C; that at Malta rose from 21° to 23°C before the discontinuity, then fell sharply to 15°C at 1200 GMT on the 3rd consistent with the presence of the sharp thermal trough.

The wind ascents at Malta (Table I) show that at 850 mb the trough did not pass Malta until 0001 GMT and the radiosonde ascents, Figures 15, 16 and 17 confirm that the main temperature fall in the lower layers occurred after 0001 GMT and before 1200 GMT.

TABLE I—UPPER WINDS AT MALTA, 2 AND 3 SEPTEMBER 1960

		2 September 1960 GMT						3 September 1960 GMT			
Height	Pressure	0500		1100		1700		0001		0500	
ft	mb	degrees	kt	degrees	kt	degrees	kt	degrees	kt	degrees	kt
2000		283	6	210	7	290	15	—	—	320	7
3000	900	300	7	230	9	310	13	260	4	280	6
5000	850	300	11	270	21	290	14	260	11	280	16
7000	750	—	—	290	24	280	16	270	24	290	23
10,000	700	300	25	300	22	290	25	270	33	290	26
14,000	600	290	29	300	27	280	30	270	33	280	35
18,000	500	310	21	280	21	290	30	280	38	290	36
24,000	400	310	19	260	24	270	36	290	39	290	41
30,000	300	260	24	250	33	270	36	270	33	290	41
35,000	250	250	46	240	63	240	63	260	63	270	47
40,000	200	250	67	240	69	240	73	250	72	260	65
47,000	150	240	68	250	59	250	57	240	66	260	57
53,000	100	260	37	240	42	260	34	250	33	260	31
60,000	70	—	—	—	—	290	16	300	9	—	—
Max. wind		240	70	240	78	240	75	260	73	250	67
Height of max. wind (feet)		39,756		40,250		36,740		34,500		42,996	

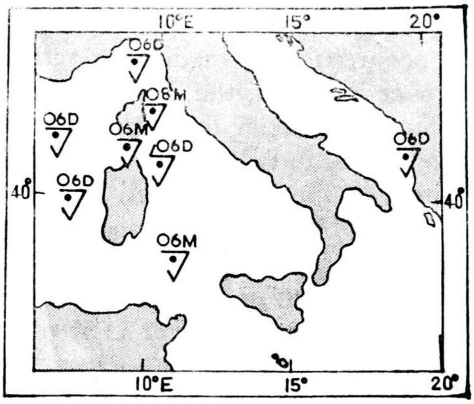


FIGURE 8—SFLOCS 0600–0800 GMT, 2 SEPTEMBER 1960

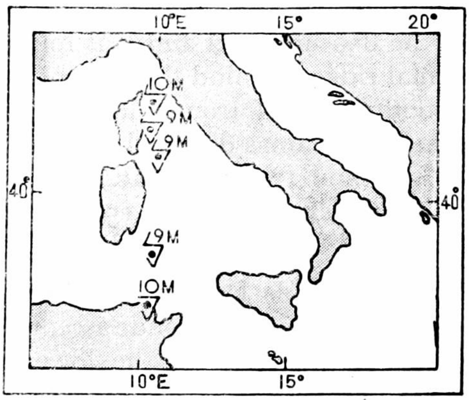


FIGURE 9—SFLOCS 0900–1000 GMT, 2 SEPTEMBER 1960

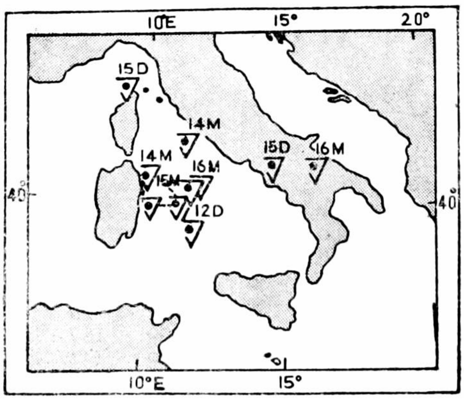


FIGURE 10—SFLOCS 1200–1600 GMT, 2 SEPTEMBER 1960

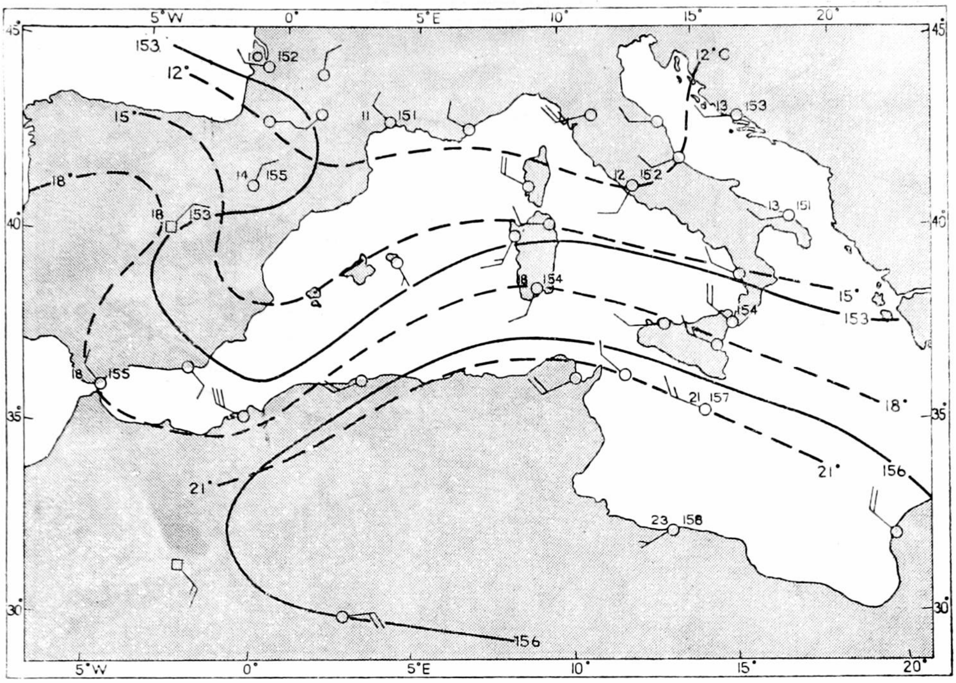


FIGURE 11—850 MB CHART FOR 0001 GMT, 2 SEPTEMBER 1960
The 850 mb contours are in geopotential decametres

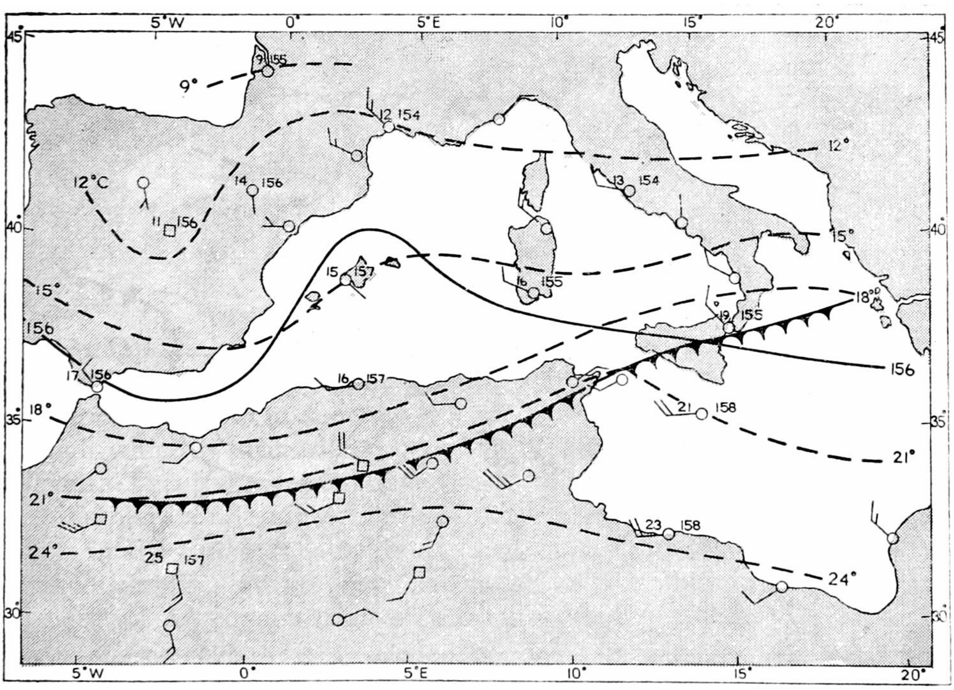


FIGURE 12—850 MB CHART FOR 1200 GMT, 2 SEPTEMBER 1960
The 850 mb contours are in geopotential decametres

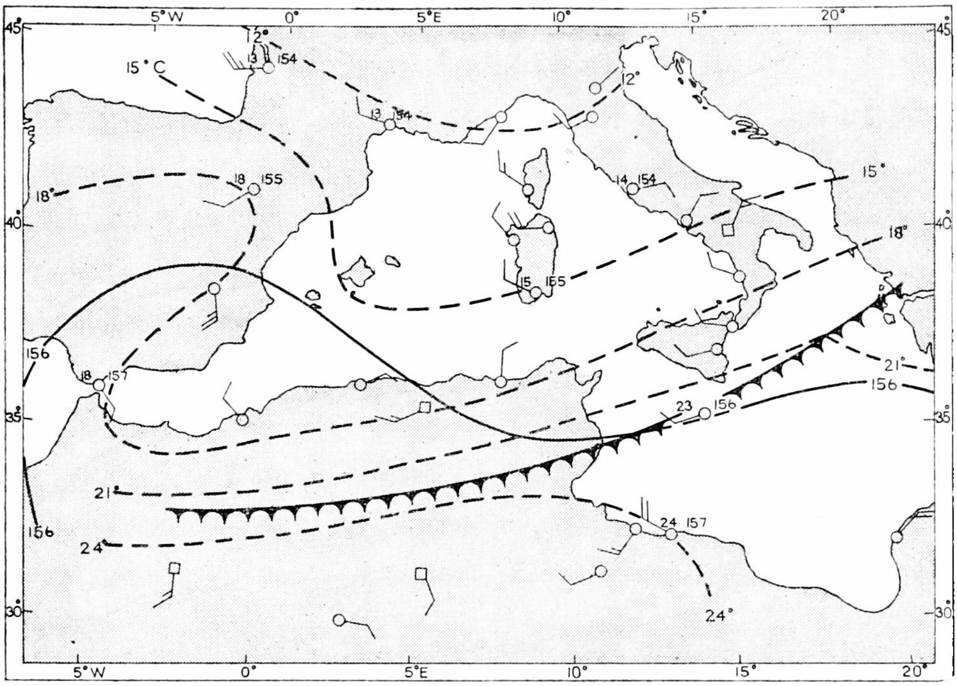


FIGURE 13—850 MB CHART FOR 0001 GMT, 3 SEPTEMBER 1960
The 850 mb contours are in geopotential decametres

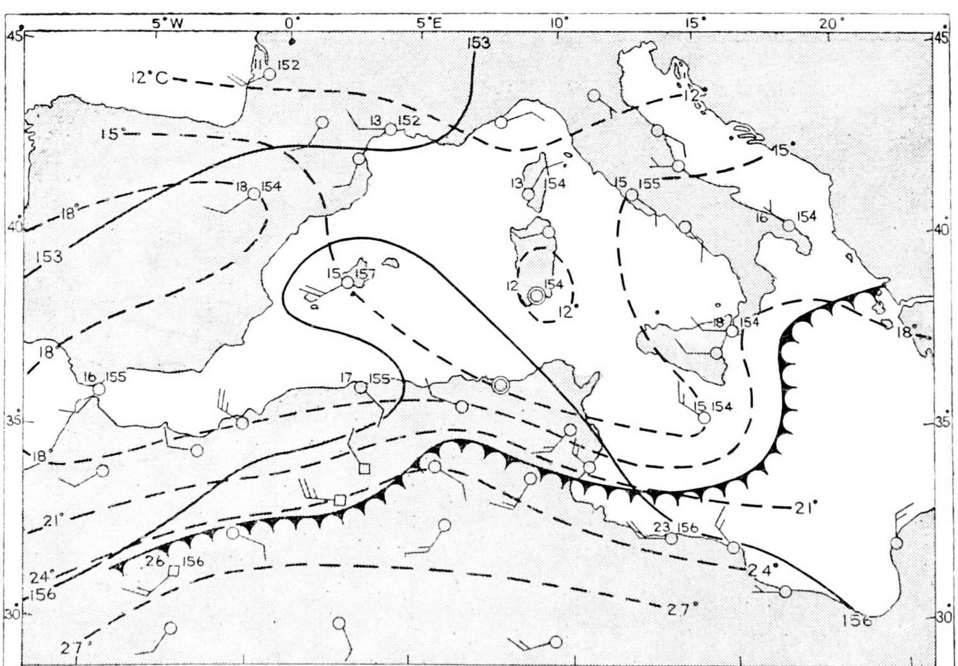


FIGURE 14—850 MB CHART FOR 1200 GMT, 3 SEPTEMBER 1960
The 850 mb contours are in geopotential decametres

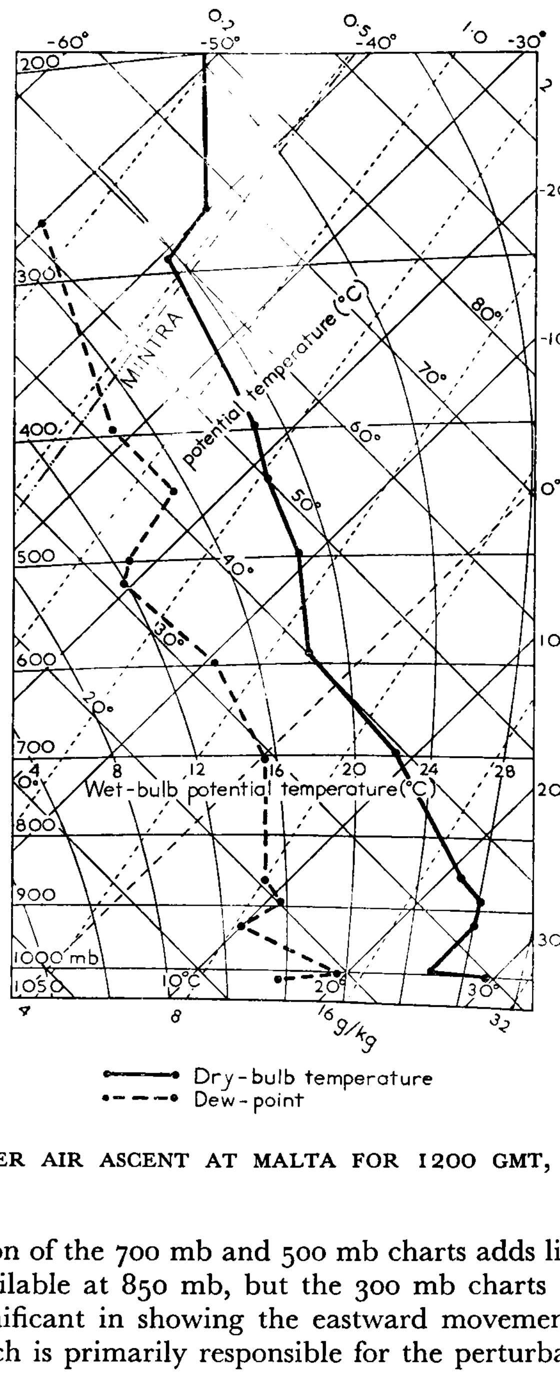


FIGURE 15—UPPER AIR ASCENT AT MALTA FOR 1200 GMT, 2 SEPTEMBER 1960

An examination of the 700 mb and 500 mb charts adds little to the information already available at 850 mb, but the 300 mb charts (Figures 18, 19, 20 and 21) are significant in showing the eastward movement of a pronounced cold trough which is primarily responsible for the perturbation of the flow at lower levels. This is typical of conditions at this time of year and the example serves to emphasize the great utility of the 300 mb chart as representative of conditions in the upper troposphere and also the fundamental importance of disturbances at this level. The association of the thunderstorms and the cloudiness with the upper cold trough is immediately evident.

The evidence shows that the main trough aloft did not pass Malta until after 0001 GMT on the 3rd. The pressure jump which occurred much earlier cannot therefore, in this instance, be directly related to the passage of this upper trough although the possibility remains of an indirect connection

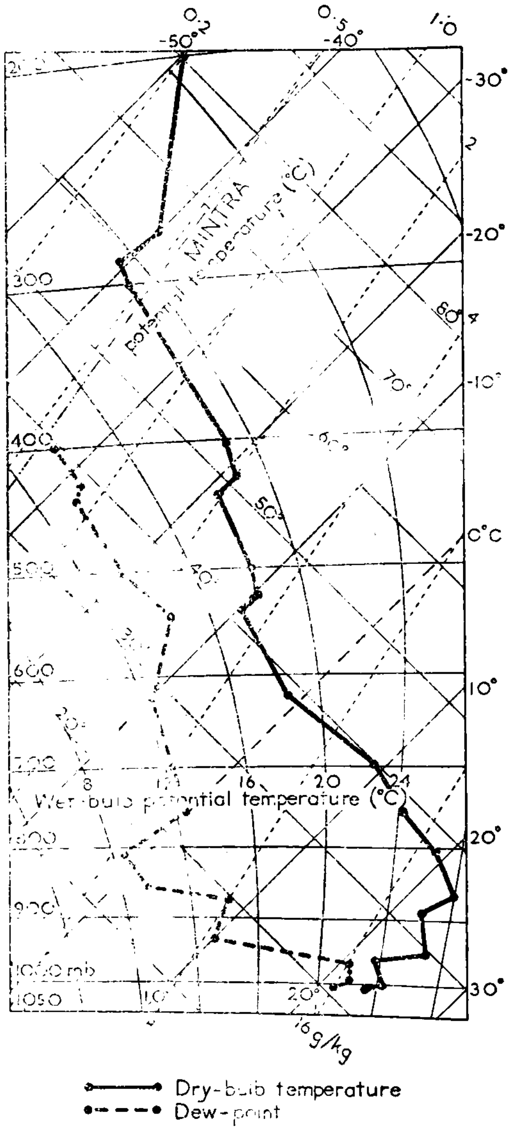


FIGURE 16—UPPER AIR ASCENT AT MALTA FOR 0001 GMT, 3 SEPTEMBER 1960

through the agency of the thunderstorm activity. We can also, following Tepper,[2] seek an explanation in terms of a modification of the low-level inversion although this effect must have been confined to levels below 850 mb. An observation at 1800 GMT of "distant precipitation not reaching the ground" to the north-west of Malta suggests the passage of an instability line and the pressure jump may be evidence of this at Malta.

For want of adequate information we shall, in this instance, ignore the problem of the origin of the pressure jump and confine ourselves to the observation that it would seem to be of direct significance in an appreciation of the situation. Knowledge of its occurrence from the barograph would have been the most positive evidence available of the imminent approach of cooler air and hence of the possibility of patches of low stratus.

The main fall of temperature at the 850 mb level occurred after 0001 GMT on the 3rd although the ascent at that time did show a slight cooling of the inversion below this level. It would be inappropriate, however, to refer to the

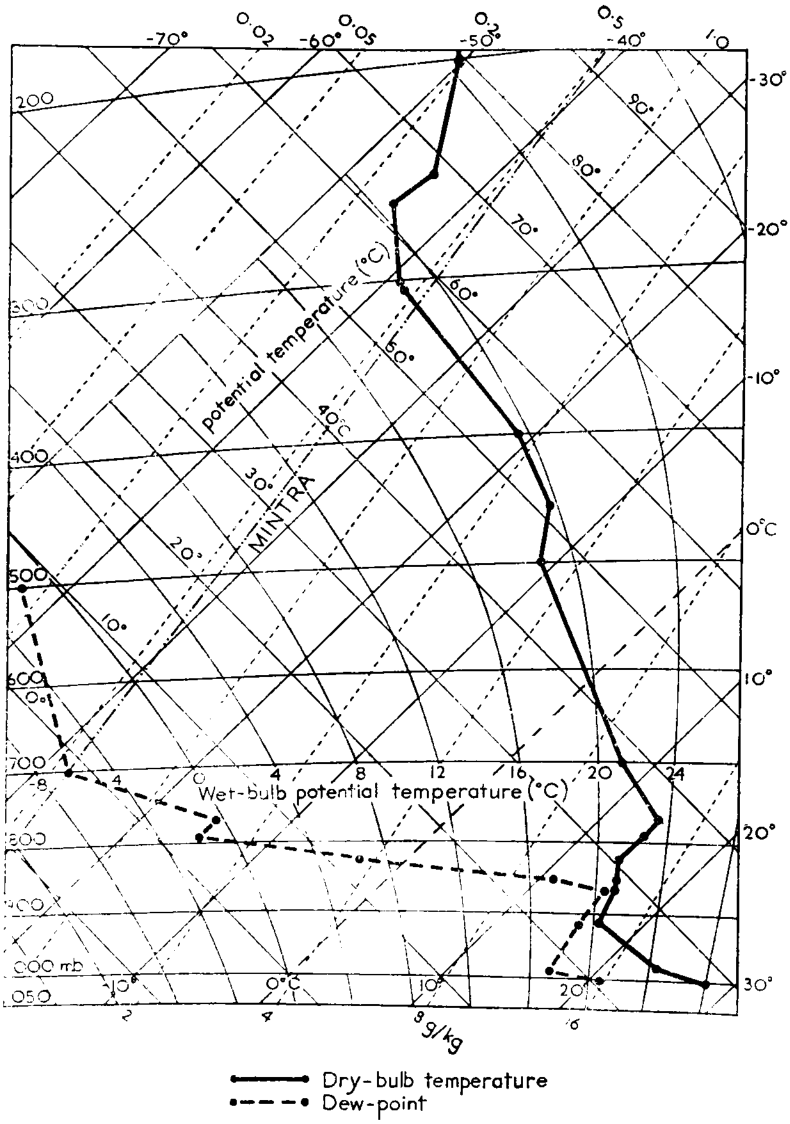


FIGURE 17—UPPER AIR ASCENT AT MALTA FOR 1200 GMT, 3 SEPTEMBER 1960

passage of a cold front; rather would it seem preferable to speak of a "discontinuity in the temperature advection field" or an "advection discontinuity".

The following observations find some illustration in the above example:

(i) Successful analysis in the Mediterranean depends, to a far greater extent than in temperate latitudes, on close attention to detail.

(ii) In the Mediterranean area, particularly in summer and the transition seasons, events on the meso-scale may be larger than those normally regarded as suitable for synoptic analysis.

(iii) In the transition seasons, strong low-level temperature gradients exist, particularly near the low-level inversion. Disturbances of this temperature field are associated with the west to east movement of troughs and ridges in the high troposphere.

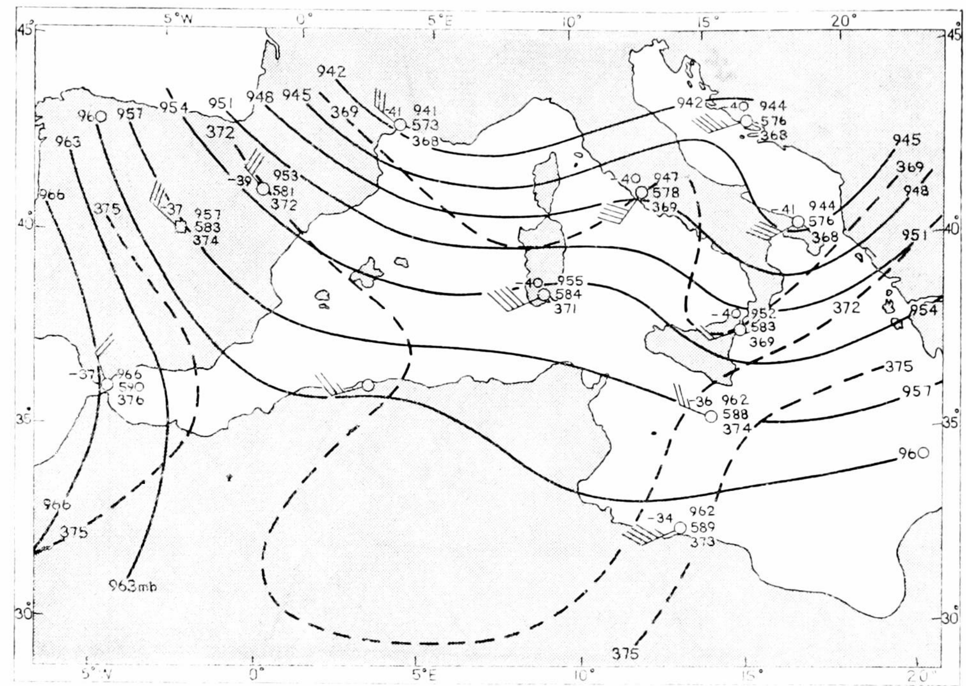


FIGURE 18—300 MB CONTOURS AND 500–300 MB THICKNESS LINES FOR 0001 GMT, 2 SEPTEMBER 1960

Both contour heights and thickness values are in geopotential decametres

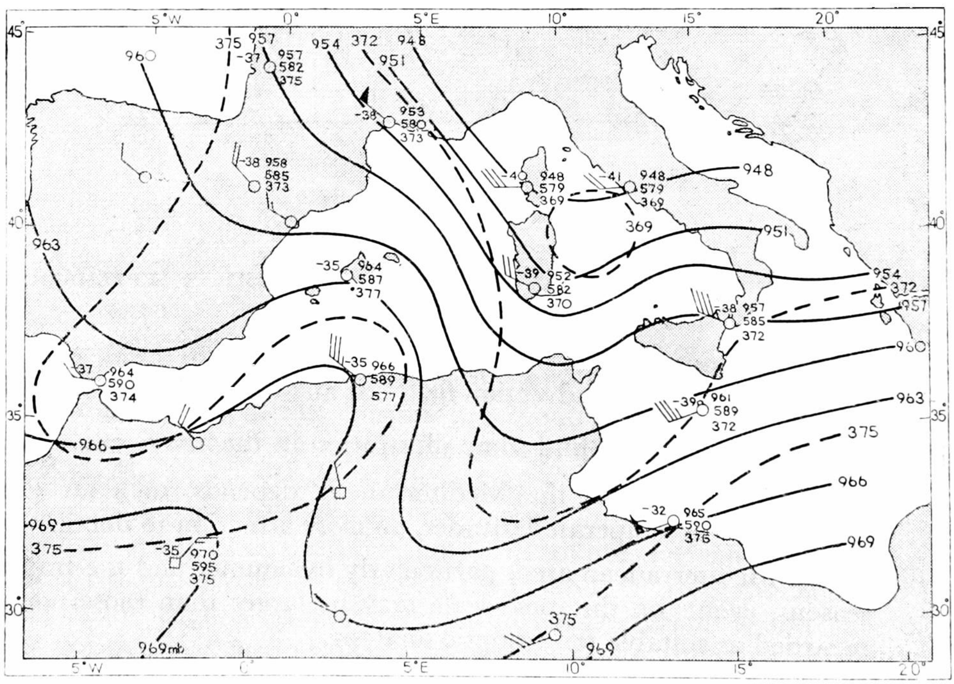


FIGURE 19—300 MB CONTOURS AND 500–300 MB THICKNESS LINES FOR 1200 GMT, 2 SEPTEMBER 1960

Both contour heights and thickness values are in geopotential decametres

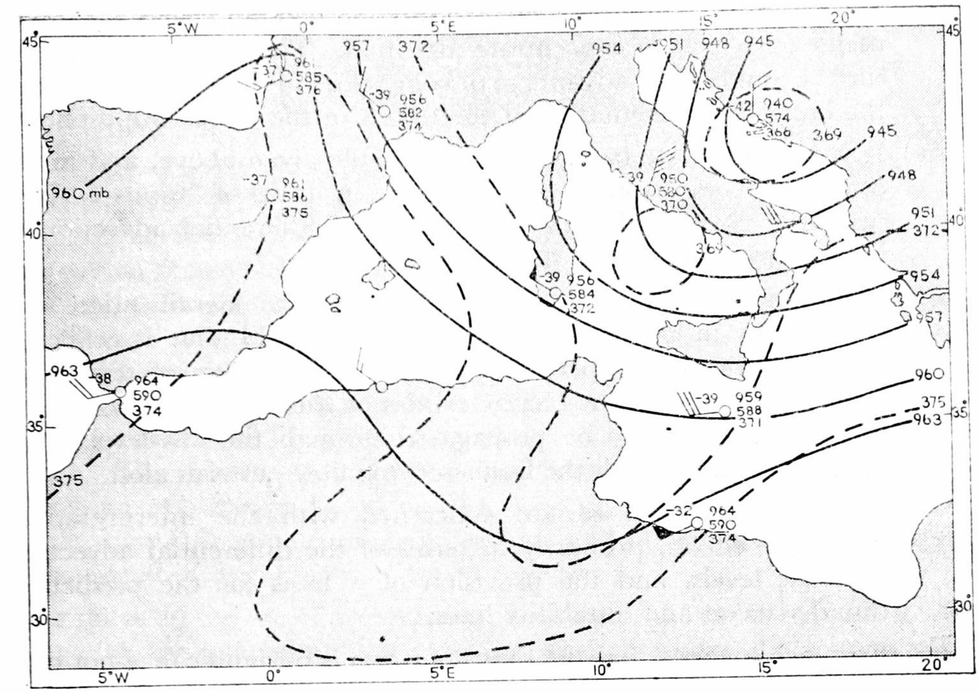


FIGURE 20—300 MB CONTOURS AND 500–300 MB THICKNESS LINES FOR 0001 GMT, 3 SEPTEMBER 1960

Both contour heights and thickness values are in geopotential decametres

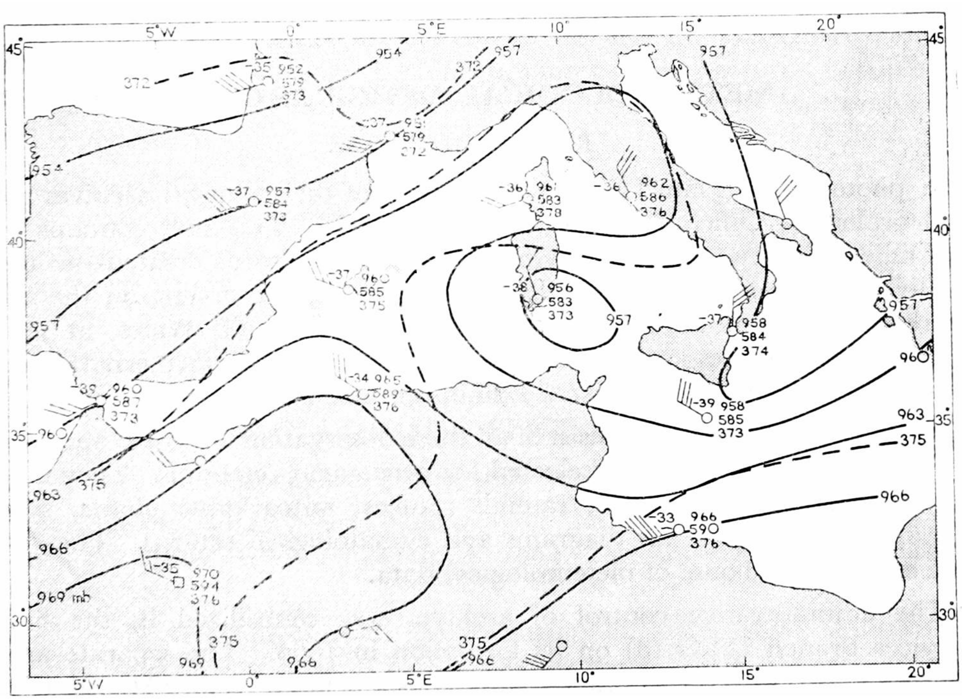


FIGURE 21—300 MB CONTOURS AND 500–300 MB THICKNESS LINES FOR 1200 GMT, 3 SEPTEMBER 1960

Both contour heights and thickness values are in geopotential decametres

(iv) For this type of situation, the 850 mb and 300 mb charts are the most useful on which to concentrate attention. The former is near to the surface and has the advantage of being close to the low-level inversion; the latter is representative of conditions in the upper troposphere.

(v) It is inappropriate in the type of example given above, and in many other instances, to attempt an analysis in terms of "fronts". We are primarily concerned with the analysis of differential advection both in the horizontal and in the vertical.

In the horizontal, the analysis aims at the identification of discontinuities in the temperature advection field that is, effectively, discontinuities of temperature gradient rather than of temperature. These have some of the characteristics of true fronts but, contrary to the latter, they may be propagated through the low-level pressure field in sympathy with the faster-moving flow patterns aloft.

In the vertical, we are concerned with the interpretation of instability effects, primarily in terms of the differential advection at different levels, and the provision of a basis for the prediction of thunderstorms and instability lines.

(vi) Evidence suggests that the pressure jump is of significance not only in meso-scale problems but also on the synoptic scale. Further examples are necessary to demonstrate this.

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.

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METEOROLOGICAL OFFICE ARCHIVES

By G. A. BULL B.Sc.

The photograph (Plate IV) shows a corner of the technical archives hall at Meteorological Office, Eastern Road, Bracknell. This hall contains on its two miles of specially built shelving the technical records created—to use the archivist's convenient term—by meteorologists and observers, on the staff of or reporting to the Meteorological Office, in England, Wales, at sea and overseas. The corresponding archives for Scotland and Northern Ireland are housed at Meteorological Offices Edinburgh and Belfast, respectively.

These technical records consist of all those observational records and working documents which have been selected for permanent retention. They contain, for example, daily registers, rainfall returns, autographic charts, synoptic working charts, upper air diagrams and climatological returns. They constitute a great storehouse of meteorological data.

The administrative control of archives was centralized in the Support Services Branch (M.O.18) on its formation in 1960. The separate archival collections of a number of branches previously held at Victory House, Harrow, and Dunstable were brought together in the archives hall in the Instruments and Storage building at Eastern Road, Bracknell, on its completion in the spring of 1962. They are cared for by a small staff which constitutes M.O.18e.

A matter of vital importance in the control of archives is the new law on the preservation of public records set out in the Public Records Act 1958 which gave effect to the recommendations of the Government's Committee on Public Records (Grigg Committee) of 1952. New rules for the selection of Meteorological Office documents for permanent preservation and for making those retained available for public use have had to be drawn up as required by the Act, a task in which much help has been received from the Air Ministry Departmental Records Officer and from officials of the Public Record Office. The Act provides that official documents selected for permanent preservation are, in general, to be deposited in the Public Record Office but a clause permits the Lord Chancellor, the Minister responsible for public records, to appoint places of deposit outside the Public Record Office for particular classes of archives, provided facilities similar to those of the Public Record Office are available. The Meteorological Office has been appointed a place of deposit following an application based on the need of public users to have expert guidance in studying meteorological records and on the great usage made of them by the staff in public services and research.

Some notes on the use of archives may be helpful to readers. Queries which may involve the use of archives will be dealt with by the branch of the Meteorological Office specializing in the subject of the inquiry (for example, M.O.3 for queries relating to climatology) and the specialist branch will advise the inquirer as to the records he needs to use. Space is available in the archives office for visitors to examine records with which they are concerned or the records may be transferred to the main building for use under the guidance of the specialist branch. The building containing the archives is a few minutes' walk from the main building eastwards along London Road. It will readily be understood that these original records cannot be lent by the archives staff for use away from the Meteorological Office premises. It is, however, possible for photographic copies to be made under the terms specified in Meteorological Office Leaflet No. 2.

A walk round the archives' shelves is an impressive experience. Here are ships' logs collected by Admiral FitzRoy, there are the rainfall returns made by the voluntary observers of Symons's British Rainfall Organization or the synoptic charts drawn by the early forecasters. In this hall set in the new headquarters buildings, one has a deep sense of the collective effort of the meteorologists and observers of the past.

METEOROLOGICAL OFFICE DISCUSSION

Forecasting dry and wet spells

The first Meteorological Office discussion of the winter season was held at the Royal Society of Arts on 15 October 1962. The subject was "Forecasting dry and wet spells".

Mr. C. A. S. Lowndes opened the discussion by giving some statistics on dry spells of three days or more at Kew for the six months from May to October. Most of the spells were associated with a spread of high pressure from the south-west or west of the British Isles. The essence of this model was the development of a slow-moving meridional type of upper flow pattern with a ridge over the British Isles. The requirements for the setting up of the model were a strong mobile upper trough over the western Atlantic and a surface anticyclone in the Azores region. Successful forecasting rules were based on measurements of upper troughs between 60°W and 50°W and the surface pressure at Horta in the Azores. Mr. Lowndes continued with some statistics on five-day wet spells at Kew. The wet spells were often associated with a slow-moving upper trough in the region of the British Isles. Successful forecasting rules were based on measurements of upper troughs between 30°W and 10°W, the surface pressure at Valentia or London and the spacing to the next upwind upper trough.

The dry- and wet-spell models both covered about half the spells which actually occurred.

A long discussion followed in which many speakers took part. Mr. V. R. Coles said that forecasters at C.F.O. found Mr. Lowndes's rules most valuable. Prebaratics beyond the 24-hour period were difficult to construct and interpret with confidence and it was useful to have other tests to deal with medium range forecasts.

The Director-General said that he found the subject of particular interest as the Office was always being pressed to extend its forecasts over longer periods. Dry spells were obviously more easy to define and investigate than wet spells. For this reason, the Office, at present, confined its notifications to the general public to dry spells. The assembly of suitable criteria defining various spells which were meaningful to the consumer was important and warnings of wet spells might be required in future.

REVIEWS

Assault on the unknown, by Walter Sullivan. 8½ in. x 5½ in., pp. xiv + 460, *illus.*, Hodder and Stoughton Ltd., 1962. Price: 30*s.*

This book gives an excellent account, by an extremely well informed layman, of most aspects of the International Geophysical Year. Written in a narrative style it relates the conception of the idea, the planning, the frustrations and the execution of the various projects which accumulated in the IGY. The author describes the men as well as their activities, dealing mainly of course with the scientists responsible for and taking part in the events. But he also makes some telling probes into the reactions of the general public (mainly in the United States) and politicians to various aspects of the IGY. After reading this immensely interesting book, one feels more than ever that the international collaboration evinced by the IGY was engendered entirely by scientific co-operation, and that the unity of this international spirit was sufficiently genuine to repress the jingoistic traits of both politicians and general public.

In the preface the author states that the emergence of science as a potent force in international affairs has taken many by surprise. The refreshing spirit of scientific co-operation is emphasized throughout the book. The author emerges as a first class advocate for scientific philosophy, particularly when it breeds this type of social behaviour.

The book is divided into 24 chapters of uneven length. The first four are devoted to the history of effects and ideas leading up to the IGY, and ten are allocated to satellites, rockets and the outer atmosphere. Only one chapter deals with meteorology, partly perhaps because it has less appeal to the public imagination; however, this subject does tend to overlap into some of the following six chapters, two each on the Arctic, Antarctic and oceanography. Two short chapters deal with seismology and gravimetry. The final chapter is entitled "The harvest", which largely speaks for itself; however the author is inclined to regard the harvest as one of international co-operation as an end in itself (marred by the regrettable stolen satellite incident). The true harvest should rather be an increase in scientific knowledge. For this reason we must hope that the very great effort and perseverance that went into the IGY, and is so well described in this book, will be matched by a similar effort in the analysis of data and the dissemination of results in the near future.

G. B. TUCKER

Tables of Normalized Associated Legendre Polynomials, by S. L. Belousov. 10¼ in. × 7 in., pp. 379, *illus.*, Pergamon Press, Headington Hill Hall, Oxford, 1962. Price: £7.

The Legendre polynominals arise naturally in the representation of a function in spherical co-ordinates, just as do Fourier series for a periodic function. In the latter case the functions necessary for computation are the sine and cosine and are, of course, tabulated as a function of a single variable. The Legendre polynomials are functions of three variables; textbooks give the formal expressions for functions and explicit expressions in the simplest cases but the functions have not been exhaustively tabulated.

The functions will clearly arise in representing any geophysical field near the earth's surface, and meteorologists may be particularly interested in representing fields such as contour heights, temperature etc. over a wide domain. The author of the tables, who is well known for his dynamical work in meteorology, found that it was necessary to extend considerably the tabulation of the functions in order to represent features of the size of depressions; he used an electronic computer to carry out the tabulation.

This volume is a translation from the original Russian text published in 1956. There is a careful account of the methods of computation used and of the possible errors. The main bulk of the book is the tabulation of $\overline{P_n^m}$ (cos θ) for $m = 0(1)\ 36$, $n = 1(1)56$ and $\theta = 0(2.5)\ 90°$ to six decimal places; no differences are given. The printing and layout seem to be adequate, though only a user could testify to this and also to the accuracy of the tables. Perhaps most possible users will have an electronic computer available and will compute such functions when they are needed in the course of a calculation. The tables will be most valuable to the occasional user who does not have the use of a computer.

E. KNIGHTING

HONOUR

We note with pleasure the election of Professor H. Amorim Ferreira, C.B.E., Director of the Portuguese Meteorological Service, to the Presidency of the Portuguese National Academy of Sciences for the year 1963.

METEOROLOGICAL OFFICE NEWS

Retirements.—The Director-General records his appreciation of the services of:

Mr. T. Herrod, Senior Experimental Officer, who retired on 10 November 1962 after over 25 years' service.

Mr. Herrod joined the Meteorological Office as an Assistant II at Sealand in 1937. He served at stations in northern England until 1945, during which time he was promoted to Assistant I. He was mobilized in the Royal Air Force as a Flight Lieutenant from September 1942 until November 1945. On demobilization he was assimilated as a Senior Experimental Officer, and served in Malta from February 1946 until August 1947. He subsequently spent 13 years at Shawbury and Preston, followed by a two-year tour of duty at Aden before his retirement.

Mr. R. J. Williams, M.B.E., Senior Experimental Officer, who retired on 31 October 1962 after 43½ years' service.

Mr. Williams left his home area (Barmouth) in 1919, at the early age of 16½ years, to come to London to join the Office as a Probationer. He spent all his career at Headquarters, including nine years as personal assistant to the late Sir Nelson Johnson (then Director of the Meteorological Office).

It is fair to say that it was while he was with Sir Nelson that Mr. Williams made his mark in the Office. During these nine years, which included World War II and consequently the handling of large numbers of important papers, Mr. Williams acquired a fund of knowledge on administration in the Air Ministry and other Departments which he was always ready to pass on to his colleagues. In the same way his experience in organizational and financial matters pertaining to the Office has been of great value on many occasions.

Problems and difficulties presented to him by colleagues visiting Headquarters, particularly during and after World War II, were listened to sympathetically and, if Mr. Williams could assist, he did not spare himself in doing so.

It was inevitable with Sir Nelson's great activity in international affairs, particularly those of the International Meteorological Organization (later World Meteorological Organization), that Mr. Williams should become involved also. He therefore played a considerable part in assisting with the arrangements for such conferences as the IMO Conference of Directors (1946) and the Commonwealth Meteorological Conference (1946).

Mr. Williams is spending his retirement in his native land and in the area he knew well as a boy. He has decided to settle in Arthog, a village on the south side of the Mawddach estuary opposite Barmouth. With the departure of "Taffy" Williams, the Office has indeed said farewell to an individual who will be greatly missed, particularly by those at Headquarters.

C.W.G.D.