A Guide to Assessing the Characteristics of Dry Thermals under Various Meteorological Conditions.

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Introduction

For the past four years the characteristics of thermals have been recorded as they came to hand. They were related to the meteorological conditions at the times of flight. In all 2470 reports were analysed during the period October 1970 to November 1974 inclusive. However, it should be indicated that the data were compiled utilising reports from glider pilots whose experience ranged from club to international level and that no attempt was made to differentiate among standard, open or sports class aircraft. Nevertheless, most reports were received from pilots using Standard Libelle machines. All flights were made in South Australia and comprised about 57 percent from Gawler, 37 percent from Waikerie, 4 percent from Balaklava and 2 percent from other clubs.

Quality of Data

Strength of thermals and rate of lift

The thermal strength was not an easy quantity to measure.

Rates of lift of the gliders were read on the variometers. This is not to be confused with the thermal strengths. Major problems in rate-of-lift measurement were to time the ascent accurately, and for the pilot to read the variometer continuously for a period of one minute. Generally, the strongest lift and the greatest height achieved occurred simultaneously during the hottest part of the day and the strongest thermals were generally found under cumulus cloud. In order to achieve consistency of method to determine the height to which the Dry Adiabatic Lapse Rate extended, the maximum temperature was used and readings of lift were those of the strongest thermals of the day. Where possible (e.g. Regattas, Competitions, and the World Championships at Waikerie 1974) many reports were gathered for the one day and a single representative reading, applicable to a Standard Libelle sailplane (sink rate of about 2 knots) was derived.

Cloud Data

Cloud details were averaged over the route during the times of flight, derived from reports by pilots and supplemented with official meteorological reports. According to Heinz Huth, cited by Fred Weinholtz . . . 'The ideal for cross country flying is $^1/_8$ to $^2/_8$ cumulus cloud.' Consequently any cumulus cloud in excess of $^2/_8$ was considered to be a hindrance and as such regarded as stratiform cloud (i.e. it cut off the sun from the thermal source). Thus $^3/_8$ cumuli were regarded as $^1/_8$ statiform cloud.

Presentation of Data

Table 1 shows the characteristics of thermals in a recognised airmass as derived from the reports and related to a set of meteorological elements, assuming no fronts nor sea breezes to be present.

In practice, all of the required meteorological information cannot be communicated in a limited time. Even if it were, it would be difficult to generalise as to which elements were the most important. This is because the accent of importance changes from one situation to another. For example, the wind may be critical on one day and the temperature may be of minor importance. Another day, the temperature may be critical because of the presence of an inversion, and the wind may be a minor consideration. Thus, no list could be compiled to show the meteorological elements in order of importance. Each element should be considered on its own merits and related to the day in question. The temperature is related to the convective depth on a given day, which has, therefore, been possible to plot the 'lift' against the vertical extent of the dry adiabatic lapse rate using the actual reports of lift. When stratiform cloud was taken into account a series of scatter diagrams could be drawn. (See diagrams 1, 2, 3, and 4.) The diagrams show faithfully, with minimal smoothing out, the periphery of all the plots. They therefore indicate as far as possible the range of the strength of lift expected for any given convective depth.

Inference from Diagrams

Correlation Coefficients

Linear correlation coefficients were calculated and are presented in the diagrams. Although the coefficients obtained were particularly encouraging a higher correlation may have been possible had a curved relationship been assumed. (A subject for further study.)

Shapes of the Diagrams

The shapes obtained were slightly irregular. Several contributary reasons were considered probable: –

1. Stratocumulus forms within a preferred height range.
2. Inversions within a preferred height range. (Particularly subsidence inversions.)
2. Altocumulus and altostratus were generally considered as stratiform types (except castellanus) and they also tend to form at preferred heights, generally above 10 000 ft in South Australia.
4. The height to which thermals extend could vary greatly from day to day depending whether or not an inversion (if present) was 'broken'. Hence few reports were received with nil to $^2/_8$ cloud and a height range of between 6500 and 8000 ft because those conditions were less common.

Table I. **Showing Thermal Characteristics in a Recognised Air Mass**

Meteorological Element	Element Pronounced	Element Weak	Remarks
Convective Depth	Thermals	Thermals	Distance apart is about $2^1/_2$ times the convective. Depth of capped by an Inversion
(Vertical Extent of D.A.L.R.)	Strong	Weak	
Diff. Between ELR and DALR	Weak	Strong	As ELR approaches DALR Convection becomes more Pronounced
Presence of Stable Layers in Pre-existing ELR	Weak in Those Lyrs even after Auto-convection has started	Strong	Stable layers in the Pre-existing ELR delay the onset of Autoconvection and Thermals are considerably weaker in the stable sections
Inversion Capping Dry Adiabatic Lyer	Arrests Thermals	Stops Most Thermals	Enhances Streeting if there is no change in wind direction with height through the Dry Adiabatic Layer
Wind Strength	Broken Choppy	Well-formed	Strong 15 kts (Winter), 30 kts (Summer)
Change in Wind Direction With Height	Broken	Slanted	Often related to type and Strength of Inversion or Stable Layer
Change in Wind Speed With Height	Cut-off or Arrested	Strength Varies at Diff. Levels	Usually related to the Pre-existing ELR even after a DALR has been established
Middle/High Level Cloud Cover	Choppy/Broken Multicentred	Better formed	Applies more particularly to patchy type cloud. eg. AC. Ci, etc.
Moisture Content in Convection Layer (Dry Adiabatic Layer)	Strong	Weak	Critical range of MR value for Gawler appears to be about 2.5 to 6.0 gm/kg. Above 6 gm/kg overdevelopment is likely. Below 2.5 gm/kg inconsistent thermals are likely.

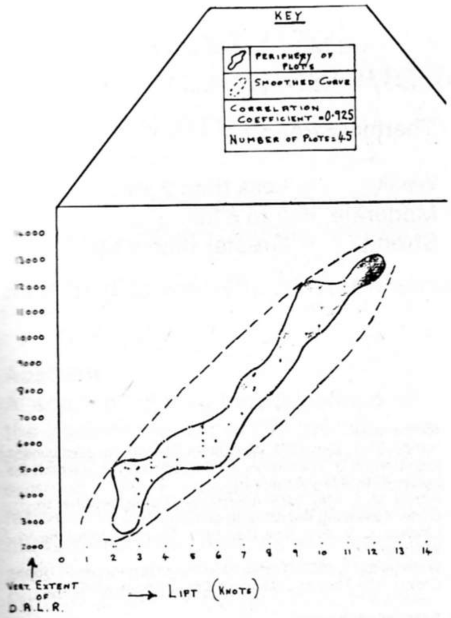


Diagram I
Showing the Distribution of Plots of Lift against Vertical Extent of D.A.L.R. with 0–$^2/_8$ Stratiform Cloud Cover

5. Data corresponding to heights below 3000 ft were unreliable, probably because temperature soundings were unreliable at those levels, and turbulence in the friction layer precluded accurate readings.

have been too small.

9. The time period of data collection was perhaps not representative of all years.

Example

The following information is required in order to use Table 1 and diagrams 1, 2, 3 and 4.: –

a) The maximum height to which the D.A.L.R. will extend for the day and the time of occurrence.
b) Expected maximum temperature and time of occurrence.
c) The time of onset/finish of auto-convection (i.e. time of start and end of thermal activity) to a height of 3000 ft, and temperature required.
d) The expected amounts of cumuliform and stratiform cloud, bases and tops.
e) Any fronts/sea breezes expected.
f) Any precipitation or thunderstorms.
g) The pre-existing E.L.R.
i) Heights and depths of stable layers/ inversions.
j) Wind velocities at all heights within the convection layer and at those heights where cloud is expected.
k) Average M.R. through the lowest 3000 ft.

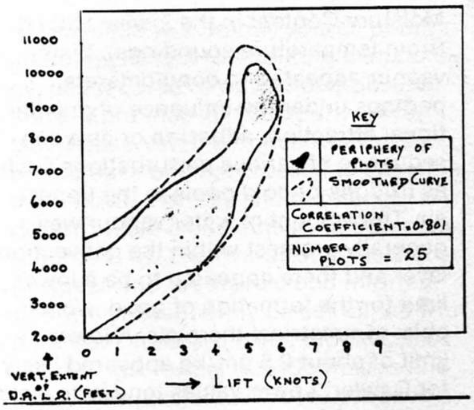
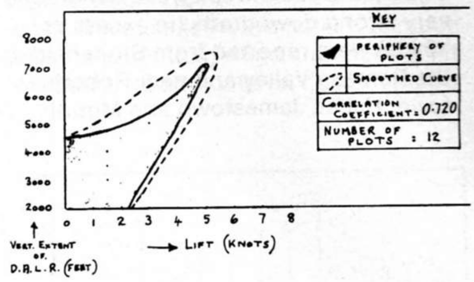


Diagram 3
Showing the Distribution of Plots of Lift against Vertical Extent of D.A.L.R. with $^4/_8$–$^6/_8$ Stratiform Cloud Cover

Diagram 4
Showing the Distribution of Plots of Lift against Vertical Extent of D.A.L.R. with $^6/_8$–$^8/_8$ Stratiform Cloud Cover



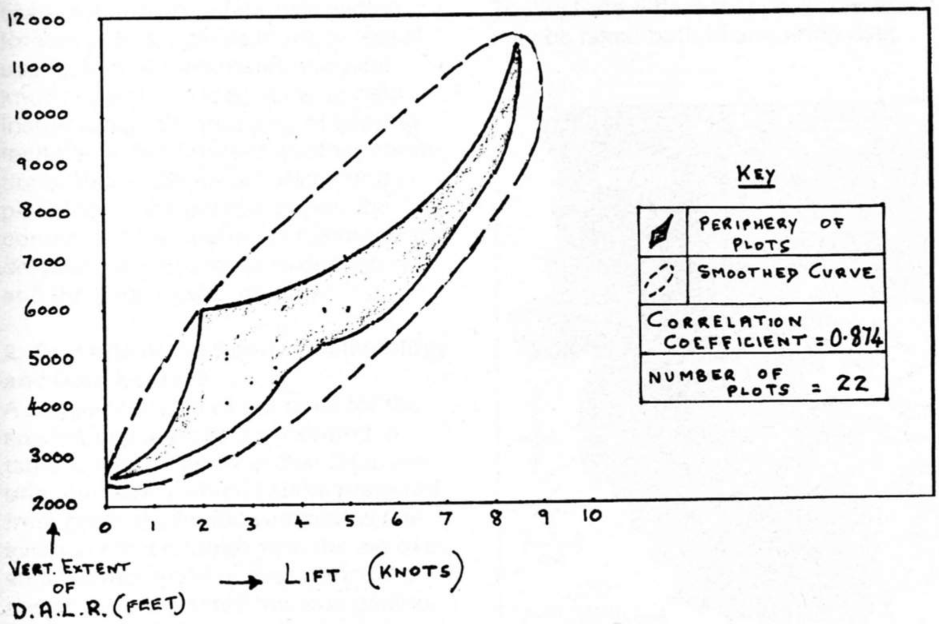


Diagram 2
Showing the Distribution of Plots of Lift against Vertical Extent of D.A.L.R. with $^2/_8$–$^4/_8$ Stratiform Cloud Cover

6. Lower readings were consistently obtained at Gawler than at Wakerie. This could have been due to a) reports from the more experienced pilots being generally received from Waikerie (e.g. National and World Competitions); b) because of undetected maritime air near Gawler stabilising the buoyancy cycle; or c) stronger thermals tended to form near Waikerie, assuming that the same convection heights were considered; or a combination of some or all.

7. The state of the ground was not the same for all flights.

8. The number of observations may

Method

From the information obtained, determine whether diagram 1, 2, 3 or 4 is applicable.

Read off the range of values obtained from the given values of the vertical extent of the D.A.L.R., and relate them to the time of day (also given): –

	Time (hours)	Height (ft)	Lift (kts)
Start	1100	3000	2–3
Best	1500	9000	7.9–8.5
Finish	1900	3000	2–3

From information received consider each meteorological element in turn to determine from Table 1 the characteristics of the thermals as follows: –

Convective Depth
Pronounced = greater than 6000 ft
Weak = less than 3000 ft
Moderate = inferred 3000/6000 ft

The Pre-existing E.L.R. If the lapse rate is almost dry adiabatic this often means an early start and a long day. Inversions and stable layers often mean a late start and a short day, and weaker thermals for the same convective depth.

Inversion Capping Dry Adiabatic Layer. An inversion capping the convection layer tends to restrict the vertical movement of the air and cause it to become stratified. Thermals forming in such flow will tend to drift in straight lines or gentle curves known as streets or streams. They are sometimes visible as cloud streets forming in line with the wind. Curved streets or streams are often found in the vicinity of the axis of a high pressure ridge.

Wind. Attention should be given to changes in wind speed and direction at all heights to determine the usefulness and workability of the thermals.

Middle and High Level Cloud. Patchy clouds tended to cut-off the sun from the thermal source and induced differential heating at an adjacent spot. This was often sufficient to 'relight' the original thermal which would then exhibit two cores, one decaying, the other developing.

Moisture Content in the lowest 3000 ft (from temperature soundings). Water vapour appeared to conglomerate, perhaps under the influence of gravitational attraction, adhesion or as a consequence of various perturbations such as troughs or cold pools in the upper air. The amount of water vapour was generally greatest within the convection layer and there appeared to be a lower limit for the formation of good, workable, symmetrical thermals. A lower limit of about 2.5 gm/kg appeared likely for Gawler. Lower values tended to yield weak, mal-formed thermals which appeared to mix more readily with the surroundings. Values of greater than 6 gm/kg tended to produce overdeveloped conditions, often associated with precipitation.

Under suspected weak wave conditions very strong downdrafts (in excess of 10 kts) were reported from Stonefield in the Barossa Valley and near Robertstown, Hallet, Jamestown and Mount Bryan, with low mixing ratio values, especially when middle or high level clouds were present.

Explanation of Terms

D.A.L.R.
Dry Adiabatic Lapse Rate . . . 2.8 C per 1000 ft or 10 C per km.

E.L.R.
Environmental Lapse Rate.

Inversion
A layer in which the temperature increases with respect to height.

Middle Level Cloud
Altocumulus or Altostratus cloud with a base usually between 8500 and 20 000 ft (2500/6000 m).

High Level Cloud
Cirrus, Cirrocumulus, Cirrostratus. Base usually above 20 000 ft (6000 m).

M.R.
Mixing Ratio. A measure of absolute humidity. Units are grammes of water per kg of dry air. Note that relative humidity is

$$\text{R.H.} = \frac{\text{M.R.}}{\text{S.M.R.}} = \frac{\text{Mixing Ratio.}}{\text{Saturated Mixing Ratio}}$$

Thermal Strength

Weak	=	Less than 2 kts
Moderate	=	2 to 6 kts
Strong	=	Greater than 6 kts

References
Hancy. M. J., Dec 1973. Australian Gliding, An assessment of the strength of Thermal Activity within a layer in which the Lapse Rate is Dry Adiabatic.
Hancy. M. J., May 1975. Australian Gliding, Weather to Glide. Assessing the Altitude of Thermals.
Lindsay. C. V., Oct, Nov, Dec 1974. Soaring, Using the Weather.
Weinholtz. F., 1968 (Translation from German by D. Hope-Cross), The Theory of Modern Cross Country Gliding.

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