Thermal Wave Soaring

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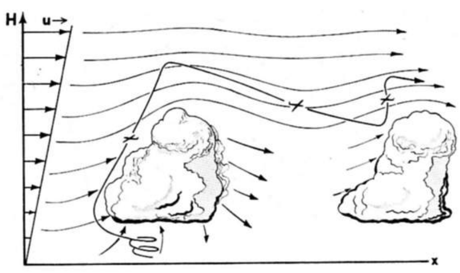
There are good indications that glider pilots in many countries have encountered a new type of lift without always recognizing its nature.
As the name implies, 'thermal wave soaring' allows the pilot to use wave techniques under specific conditions of thermal convection. It also suggests the possibility of climbing outside cumulus clouds in clear air to heights exceeding the cloud tops.

1. The Cumulus Wave

It seems to form under conditions of vertical windshear, that is, an increase of horizontal wind with height.
Evidence for this first type of 'thermal wave' soaring revealed itself when we interrogated experienced sailplane pilots during the Gliding World Championships in Leszno (1968) with regard to the second type of thermal waves to be discussed later. The typical experience reported is as follows:
Using normal circling techniques, the pilot reaches cloud base and tries to move away from the cloud to avoid instrument flight. If he moves sideways or downwind, nothing of importance happens, but if he moves upwind and the wind is strongly increasing with height, the climb rate continues to be positive after emerging from under the cloud. The sailplane begins to climb on the outside of the cumulus cloud in very smooth lift. This appears to hold also for large cumulonimbus. The flight technique suggests itself: It resembles slope soaring, the cloud being the mountain slope with the wind blowing against it. (Figure 1). Instead of fighting instrument flight conditions in the turbulent interior of the cumulus cloud, one uses the weak, but persistent and smooth wave lift outside the cloud and, if lucky, does not only reach the top of the cloud but continues beyond it.
At this time we can only guess that we have here a combined 'obstacle' and 'entrainment' phenomenon resulting in a wave motion on the upwind side equivalent to the 'bow-wave' of a ship. The reason appears to be the following: If the wind increases strongly with height, the rising air mass in a cumulus cloud, originating near the ground, carries its horizontal momentum upward losing it only slowly, through mixing with its environment. The cumulus, therefore, moves slower than the upper wind; it propagates upwind with respect to the air, while drifting downwind with respect to the ground. We have some measurements and theoretical estimates of the relative speed of cumulus clouds under vertical windshear conditions by J. Malkus (1949, 1952, 1954) taking into account both the entrainment of ambient air into the vertical 'jet' of the thermal and the form drag due to its cylindrical shape. These early investigations now become timely from a soaring standpoint. They suggest that active cumulus clouds move with about half the wind speed difference between the ground and the ambient air at any given height. As a result of this, the cumulus clouds tilt downward in a predictable way giving a visual indication that conditions are favorable for thermal wave soaring.
One may imagine the cumulus cloud to be a 'porous' obstacle in a horizontal wind current. The flow goes over and around the obstacle, but it also penetrates it.
It has been known for a long time that cumulus clouds entrain outside air uniformly from all sides as they rise. This has a twofold effect: Drier (and usually colder) air mixes with the humid air rising from lower levels, increasing the mass of the cloud, but decreasing its buoyancy and its liquid water content.
Under conditions of vertical windshear, however, this mixing process becomes asymmetrical and is apparently organized in such a fashion that a regular 'entrainment current' forms on the upwind side and a 'detrainment current' on the downwind side. (The latter is often visible, as cloud fragments drift away and dissipate on the downwind side). This current enters the upwind sidewall of the cumulus cloud under an angle, its vertical component being directed upward, its horizontal component toward the center of the cumulus updraft and in the direction of the prevailing wind. This agrees with the observation that, under windshear conditions, the updraft is on the upwind side, the downdraft on the downwind side.
The entrainment current is probably stably stratified since the vertical stratification of the ambient dry air is stable. The entraining air therefore has the ability to form waves. If we consider the entrainment current as a wavelike phenomenon, we can understand why it propagates together with the cumulus against the wind relative to its environment and why it has the laminar characteristics of a mountain wave. Whether or not a temperature inversion capping the convective layer is required to excite this wave remains to be seen.
It is too early to give reliable values of updrafts to be expected in this wave-lift outside the cumulus cloud. Observations and some physical considerations suggest that for a vertical windshear of 5m/sec per km (3 knots/1000 ft.) the rate of climb will be of the order of 1 m/sec. (200 ft/min) – weak, but consistent.
To use this type of lift the flight technique resembles that of wave soaring in front of a weak wave cloud. The nose of the sailplane is always pionted a little away from the cumulus cloud. Wave soaring experts recognize this wave lift right away. It can often be reached from under the cloud base by penetrating into the wind. It may at first be quite weak.
If the cumulus wave lift reaches much above the cloud top (lenticular caps sometimes indicate this) one may be able to hop from cloud top to cloud top without ever having to enter the cloud. (Figure 1). Herold (1972) seems to have done this.

Fig. 1. Thermal wave soaring: The Cumulus Wave.



2. The 'Cloud Street Wave'

This is a second type of thermal wave, which is better explored.
It was reported at the OSTIV Congress in Leszno (1968) by Dr. Jaeckish, Hamburg, Germany. His paper is published in OSTIV Publication X and obtained the OSTIV prize. It is described here briefly.
Cloud-streets are often capped by a strong inversion and a sharp change in wind direction. Since most cloud-

streets are oriented in the direction of the low level wind and since the up and down drafts deform the inversion into a wave shape, the upper air will climb and descend over the topes of the cloud-streets and induce a general wave motion in the middle troposphere. The intensity and vertical extension of this wave depends on the stratification and wind speed of the upper air and the spacing of the cloud-streets. Figure 2 depicts this situation. Figures 3 through 5 show examples of aerological soundings for three sailplane flights discussed by Jaeckisch. Two of these flights have been described earlier by Kant (1965) and Reinhardt (unpublished). In each case the upper flow is directed approximately 90 degrees to the lower flow. There is evidence that thermal waves also develop under conditions of dry thermals. (See Figure 3). As Jaeckisch has pointed out, the spacing of the cloud-streets is close to the critical wavelength of the upper flow given by its natural frequency. To what extent this spacing is determined by the upper flow remains to be seen, but it is entirely possible that convection chooses cell dimensions which allow maximum amplification (J. Kuettner, 1971). It appears that one can reach the wavelift from under the cloud-base only, if the clouds are shallow.

The flight technique is apparently quite similar to that applied to isolated cumuli. The main difference is that the pilot can soar at high levels along and above the cloud-streets which in this way mark his course like a highway or airway. That the technique has not been used widely is probably due to the fact that most pilots who have run into this phenomenon have interpreted it in various ways or have just been puzzled.

Again it is too early to state reliable values of updrafts to be expected outside the cloud-streets. Some observations indicate that they may reach higher values than in the cumulus wave. The maximum rate of climb may vary from 1 to 2 m/sec depending on the vertical windshear.

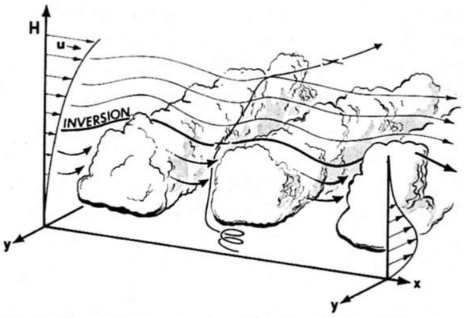


Fig. 2. Thermal wave soaring: The Cloud-street Wave.

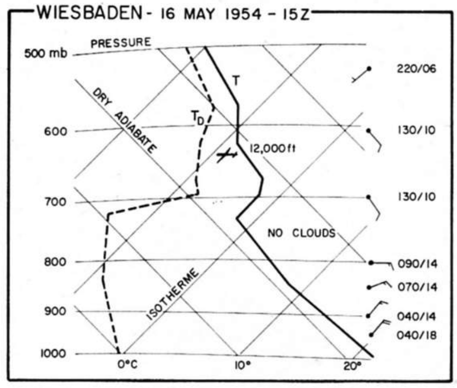


Fig. 3. Atmospheric conditions for thermal wave soaring without clouds. Note inversion and change of wind direction with height. Wind speed in knots. (After Kant. 1965)

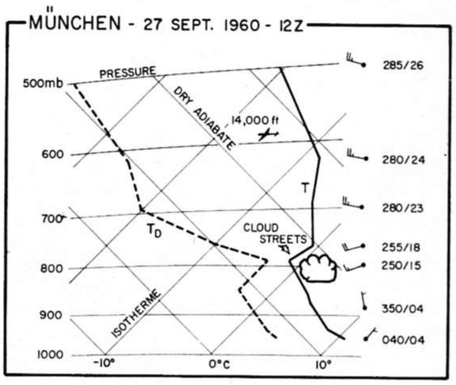


Fig. 4. Atmospheric conditions for thermal wave soaring in 'cloud-street wave'. Note inversion and change of wind direction and speed with height over connective layer. (After Reinhardt and Jaeckisch)

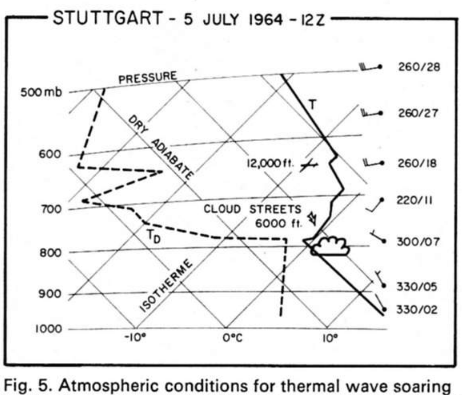


Fig. 5. Atmospheric conditions for thermal wave soaring in 'cloud-street wave'. Note inversion and change of wind direction and speed with height over convective layer. (After Jaeckisch)

3. Information Needed

To learn more about thermal waves, it is important to establish the frequency of this phenomenon and to fully understand its physical mechanism.

It appears that the thermal wave is often confused with 'rotor clouds' in mountainous terrain (which are usually stationary with respect to ground) or with 'shear waves' (which have a much smaller wavelength), even with 'sea breeze' shear zone' lift and with dissipating mountain waves (which sometimes drift away).

Numerous flight observations exist already. The author has many reports from Germany, Italy, Australia and the USA These flight reports – though interesting to read – are often of limited value because they do not contain the necessary minimum information or they combine factual observations with interpretative speculations. One thing, however, seems to be certain: Thermal waves are widespread and frequent. In addition to Jaeckisch, Rovesti's and Ferrari's pioneering work on the 'termo onda' must be mentioned here (see references).

To learn more about thermal waves it may be helpful to suggest what observations should be made and documented, at least during future thermal wave flights:

(1) Date, type of glider, take-off and landing place and time; height of terrain over sea level;
(2) Physical map showing flight track, terrain, cloud distribution, etc.;
(3) Estimated surface and upper wind direction and speed. (State heights over sea level);
(4) Approximate height (over sea level) of base and tops of cumulus clouds.
(5) Did you climb on the outside of cumulus cloud? (What side?);
(6) If so, describe technique; rate of climb; height of beginning and end of climb; top of lift with respect to cloud top; estimated wind direction and speed during climb;
(7) Were clouds isolated or organized in streets?;
(8) Did clouds and lift areas drift or were they stationary with respect to ground?;
(9) Estimate drift (direction and speed) of clouds and life area;
(10 If cloud streets existed, what was their orientation and drift (if any)?;
(11) Describe, if possible, up and down draft distribution under and around cloud;
(12) Do you have experience in wave soaring? If so, were there mountain ranges or hills upwind which in your opinion may have caused lee waves?
(13) Were clouds tilted with height and in what direction?;
(14) Make sketches of clouds and climb and describe other interesting observations. Include barogram with notes, if possible.

To enhance the store of information about this new soaring technique every glider pilot is encouraged to venture from under the cloud base into the upwind side of the cumulus by penetrating against the wind and looking for weak smooth updrafts. This is especially promising on days when the cumulus clouds tilt downwind or when other information indicates that the wind are strongly increasing or turning with height. If possible, notes should be made *during* the flight.

The author will be happy to receive and collect such flight reports, under the following address:

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Publication of the more interesting flight observations will be encouraged.

Conclusion

The type of updraft described – a combination of thermals and free waves – may open the door to a new technique for cross country and altidute flights even over the plains, avoiding instrument flight inside clouds. It has obviously been used already by many (more or less surprised) glider pilots interpreting the lift in various ways. Indications are that the phenomenon is widespread and frequent. Once its nature is firmly established it may be expected to be used widely and to present a most comfortable and enjoyable way of riding the atmosphere.

References

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