# Convection cloud systems

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**Summary**

The interaction of rising and environmental air is considered to be the main reason of the life cycle of convectional circulations composed of early, mature and dissipating stage. Wind shear causes deformations of otherwise symmetrical circulations resulting in special Cu cloud forms. The effect of varying upper air moisture on the diurnal march of convective cloudiness is discussed.

The mentioned features in suitable combinations often affect large areas and determine the development of certain convection cloud systems on the mezoscale or even on the synoptic scale. The distinction of isolated Cu or Cb cloud formations, of convective waves and streets permits us a better understanding of nonfrontal weather development and of its more efficient use for cross-country flying.

## 1. Introduction

The Meteorological Service has often to provide detailed forecasts of convection clouds for the purpose of aviation and particularly of soaring. With the current working methods using synoptical charts and aerological ascents conclusions on convection updrafts can be made, but not on the precise structure and development of convective clouds.

This is due to the relative sparseness of meteorological stations and to the shortcomings of the current codes used in meteorology to express the convective cloud state in a more detailed way. But the combination of precise aerological measurements, the synoptic situation and the careful observation of the local state of the sky gives a sufficient basis for a much more accurate estimate of convection clouds and nonfrontal cloud systems.

## 2. Observational data

The following paper is based on detailed observations of convective clouds on 69 days selected during the last 8 years.

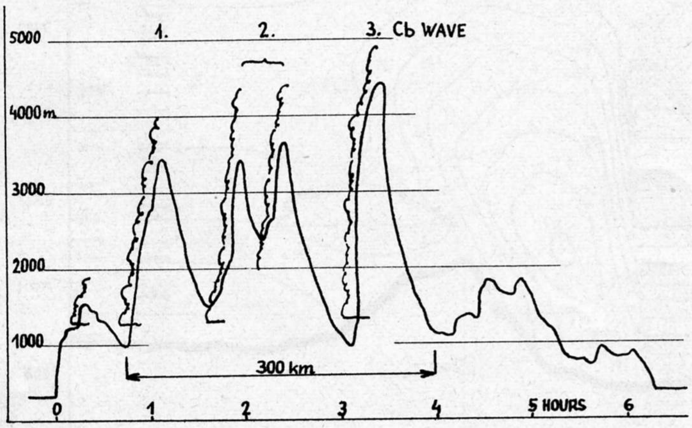


Fig. 1 Barogram of a cross-country flight, during which 300 km were covered in about 3 hours. Three successive wave-like thunderstorms were used for gaining height of about 5000 m in each of them before jumping through the clear space

Since 1955 these data are supplemented by photographs of typical cloud forms.

In 31 cases detailed glider reports were available.

The cloud types studied were the following:

- Development of small convective circulations under calm conditions (fair weather cumulus, clear air convection).
- Cumulus deformations due to wind shear.
- Effect of varying upper air moisture on the diurnal variation of convective cloudiness.
- Extension of small scale effects to mesoscale and synoptical conditions (waves and streets of shower and thunderclouds).

Since 1955 detailed convection forecasts were made especially for glider pilots testing the actual conditions. An example of a cross-country flight carried out with the use of wave-like thunderstorm convection is presented in fig. 1. The

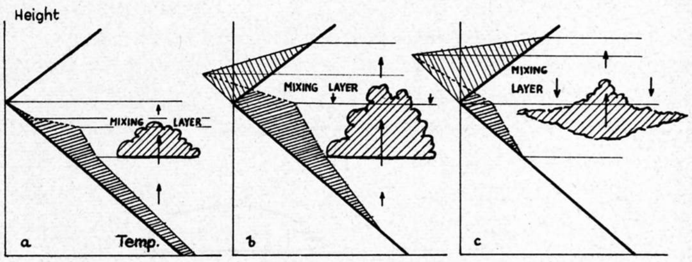


Fig. 2 Suggested temperature distribution along the axis of a thermal during its three development stages and schemes of appropriate cumulus cloud forms under calm conditions: $a$ = early stage, $b$ = mature stage, $c$ = dissipating stage

cooperation with glider pilots has been most useful, especially for the last of the above mentioned points.

Shower and thunderstorm clouds have also been observed by means of radar during the last years.

## 3. Interaction of rising and environmental air

(*a*) *Calm conditions.* A volume of warmed air rising from the ground through the convection layer is transporting its properties to higher levels. At the same time it is subjected to the effects of the environmental air, such that the actual motion at any instant is a result of the interaction of both, the rising and the environmental air.

The interaction depends on the stability and wind shear of the free atmosphere. In this section there will be mentioned the changing rate of interaction due to various stability effects under calm conditions. The temperature excess of the air ascending through an unstable layer determines the upward velocity and the entrainment of environmental air.

Fig. 4 Typical small cumulus clouds during the "first interval of convection," following often after clear mornings

When the top of the convection layer is reached, stably stratified upper air is forced to rise just above the still rising warm air coming from below.

The upward velocity is reduced to zero when the volume of the warmed air is exhausted by mixing with the upper cooled air in a growing mixing layer and is spreading out radially from the middle of the weakening updraft. Finally the subsidence of the upper air starts, first on the outer parts and gradually over the whole area of the previous updraft. Occasionally a downdraft may develop throughout the convection layer as the final stage of the small scale convective circulation.

The vertical temperature distribution along the axis of a convective updraft characterizes the three development stages (fig. 2), i.e. the early, the mature and the dissipating stage.

(*b*) *Wind shear effects*. A well developped wind shear causes the concentration of up- and downdraft on opposite parts of an individual cloud. If the wind gradually *decreases* with height, the updraft is stronger (and remains for a longer period) on the downwind part of the cloud.

First signs of the downmotion will be observed on the opposite (upwind) cloud section, where the cooled upper air from the area just above the swelling cloud top is concentrated. Gradually there appears a downdraft of a velocity equivalent to that of the updraft. The downmotion spreads finally to the entire cloud mass, which soon disappears.

An *increasing* wind with height causes the opposite distribution of vertical drafts with respect to the cloud. The upwind section of the Cu cloud contains the updraft which may be expected in the cloudless area, too. The cooled air above the bulging cloud tops is now accumulated over the downwind portion of the cloud. Later on in this area appears the downdraft.

The mature stage of this cloud type is illustrated in fig. 3.

Fig. 3 The active rear section of an isolated Cb-cloud moving slowly away in the view direction. The upper wind is blowing in the same direction and is gradually increasing in higher levels

## 4. Diurnal variation of convective cloudiness

It is well known that the amount of convective clouds usually does not remain the same during the entire day. There may be periods of active Cu clouds alternating with periods of prevailingly passive cloud formations. This is due to the sudden accumulation of many small Cu clouds in the early and mature stages during the "first interval of convection" (fig. 4) and due to the slow dissipation of various individual cloud formations.

Fig. 5 Later interval of convection with Cu-clouds concentrated in more extended, but isolated formations. The space around these Cu or Cb clouds contains many layered, slowly dissipating cloud forms. Isolated small Cu-clouds are lacking entirely

During the second and further "*intervals of convection*" some dissipating cloud formations will be present, often in the form of well extended Sc and Ac sheats. Therefore short hops with a sailplane (up to 100 km) may be quickly and safely carried out during the first interval, while later on in most cases some difficulties must be expected.

The amount of convective cloudiness depends on the *moisture* conditions in the upper half of the convective layer. "Dry air" defined by a difference $t - t_d$ of about 10° C ($t$ = temperature, $t_d$ = dew point) supports clear air convection or quick dissipation of Cu clouds. The amount of Cu clouds will remain smaller than 4/8 all day long.

"Moist air" defined by $t - t_d \cong 4 \div 2°$ C supports Cu cloud development with about equal duration of early and dissipating stage. The cloud amount will remain about 4/8 with changing alternately within the limits of 2/8 — 6/8.

"Very moist air" ($t - t_d < 1°$ C) extends the duration of the dissipating stage to hours. Occasionally, after clear mornings and the first interval of "convection" a thick Sc layer may develop to late afternoon.

## 5. Nonfrontal cloud systems

(*a*) *Isolated cloud formations.* Wind velocity and moisture increasing with height but with only small change of wind direction in the upper half of an extensive convection layer (> 3000 m) supports the development of well extended, but isolated cloud formations with long lasting dissipating stages. Occasionally local showers may develop in the lee of strong heat sources.

Interesting there are the convection cloud variations by greater depth of convection layer. The "first interval of convection" remains unchanged, but later on extensive "deaf areas" without updrafts and small Cu clouds develop (fig. 5).

This represents serious difficulties for a cross-country flight. The unfavourable areas shadowed by slowly dissipating layer clouds are increasing gradually after the first shower cloud has developed.

Under these conditions it is not advisable to delay the take-off and to wait for a second "improved convection interval." Weak, but frequent updrafts during the first interval without "deaf areas" can be used.

(*b*) *Cloud waves.* Wind velocity decreasing with height and no or small change of wind direction, but very moist air in the upper half of the convective layer favor the development of wave-like convective formations extending perpendicularly to the mean wind. Tens of kilometers wide frontal zones of this wave type are composed of many growing Cu clouds gradually increasing in amount. Downdrafts of importance are rare in the area of this frontal zone.

There follows a much wider rear zone containing layered, slowly dissipating cloud forms. The total width of both zones is usually about 100 km. The rear edge of the dissipating zone of this cloud formation preserves often a striking uniformity.

Sometimes many successing waves are moving by a fixed locality causing alternating periods of clear sky, of increasing amounts of Cu clouds (the appearance corresponding to the first interval of convection in isolated cloud formations) and of completely obscured sky with Ac, As or Sc, St. The front edge of such a "wave" is constantly propagating due to the sudden development of new Cu clouds, while the rear edge is constantly dissipating.

The surface temperature reaches its maximum just before the passage of the frontal zone and drops suddenly near the rear side of this zone. It remains low during the overcast period and increases gradually under clear sky after passage of the rear edge. This process repeats itself all day long when the flow and moisture conditions remain unchanged. Thus, the convection waves regulate the surface temperature within certain limits.

The described structure of the convection waves requires an appropriate tactics for cross-country flights—namely to remain with a sailplane in that part of the frontal zone where the Cu clouds are in their early stage and not to try "to outrun the weather," since the possible gain of altitude may be insufficient to reach the preceding cloud wave.

(*b*) *Cloud streets.* Another cloud system appears with well developped veering or backing of the wind when the air is moist ($t - t_d \doteq 2 \div 4°$ C). A high instability and the limitation of the convective layer by a pronounced inversion are also significant factors. Any beginning Cu cloud is propagated by a screw-like motion in the mean wind direction.

Shortly after the beginning of convection many parallel streets of Cu clouds, corresponding to the mean wind direction, are developed. On opposite sides of any cloud street the up- and downdrafts are concentrated and the same vertical motion is affecting the close clear air area, too. Inside of the clouds there occur unusually rough flying conditions. The cloud streets may be preserved for long periods, but with a very slow lateral motion to the active side.

Any of the three convective cloud systems may occur on the local as well as on the synoptical scale depending on the depth of the convective layer.

Isolated showers or even thunderstorms reveal appropriately different structure and intensities if compared with wave- or street-like forms. The isolated thunderstorms are known to develop hail, but no gusty winds and no turbulence of importance. There prevail horizontal flashes among various parts of the extended cloud mass.

Wave- and street-like showers or thunderstorms are very turbulent cloud formations. There are strong and gusty surface winds, but hail at the ground is rare. Flashes between the cloud mass and earth surface do prevail. The wavelike thunderstorms are always producing dangerous squalls in front of the precipitation area. They represent the fastest type of nonfrontal thunderstorms and are often considered as secondary fronts on synoptic charts.

## 6. Conclusion

The above descriptions of Cu cloud formations and systems are based on observations and on soaring experience gained in middle Bohemia (Praha) and in Poland (Leszno 1954, 1958). They were made in the plains and cannot be applied to mountainous regions without considerable modifications.

Any change of moisture or of wind conditions during the day is connected with a corresponding change in convection cloudiness. The wave-like systems may be replaced by common, isolated Cu clouds due to decreasing moisture or even by cloud streets if the wind veers or backs.

These changes of cloud forms can be observed from the sailplane and may indicate what flying tactics should be used.

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