FAST AND SLOW DEVELOPMENT OF THUNDERSTORMS

by Dr. Jiří Förchtgott

Presented at the XXI OSTIV Congress, Wiener-Neustadt, Austria (1989)

Some tens of years ago, two glider pilots planned to fly a 500 km triangle over Bohemia. Both of them were experienced airplane pilots, so their knowledge of the weather was unquestionable. On 'D' day, they started as soon as possible with expected cu development in the sky. However, one hour later they were surrounded by thunderstorms and forced to land. The rest of the day was thunderly with heavy showers all over the area.

Again, as a result of the official forecast at our National Championships in Nitra, one day about 30 competitors departed for long flights with the same result as above.

I don't agree with such a hopeless position of meteorology in connection with forecasting thunderstorms. The content of the aerological TEMP reports today is sufficient to inform very precisely the likely convection at the beginning of any day — inclusive of thunderstorms. (The only question for a glider pilot might be how to get the appropriate TEMP data.)

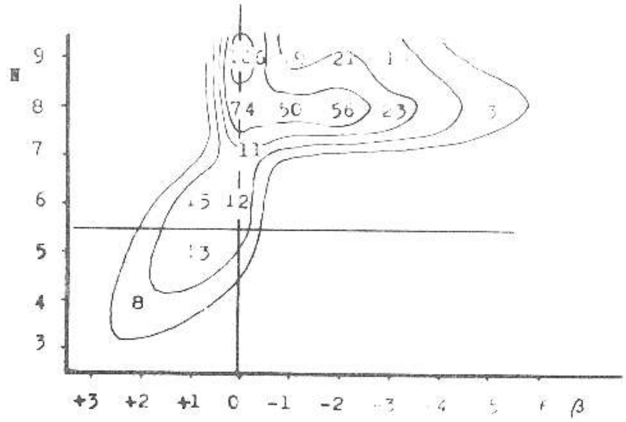

Figure 1: Occurrence of thunderstorms of various intensity (N) in relation to the upper air humidity (ß). July 1972, Bohemia and Moravia.

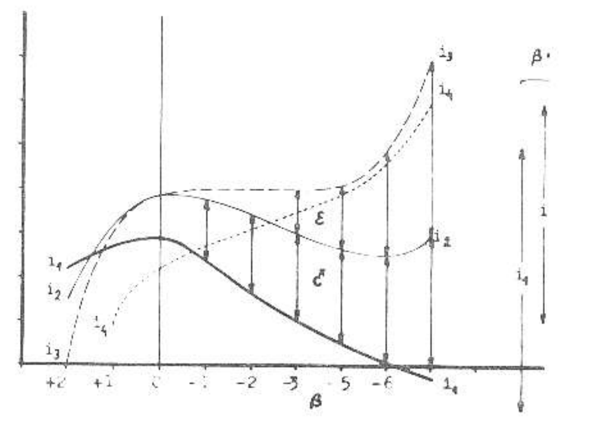

Figure 2: Instability changes expressed by indices i_1, i_2, i_3, and i_4 depending on upper air humidity ß for 78 strong thunderstorms, Czechoslovakia, June to August 1973.

Bohemian Thunderstorms

July, 1972 was a month with unusually high thunderstorm activity in Bohemia and Moravia. Meteorological stations reported as many as 427 thunderstorms, of which 368 were heavy. Figure 1 shows the thunderstorm dependance on high (+ß) and low (-ß) air humidity within the convection layers of various heights (N). N=4 to 7 corresponds to light and moderate thunderstorms, while N=8 or more means heavy thunderstorms (Table 1).

Light thunderstorms with limited convection layers — cold air advection from W to NW — need very humid air for their real development (ß > D). Heavy thunderstorms on the contrary are developing in dry air mostly (ß ≤ 0). The parameters N,ß were chosen in such a manner as to allow simple and direct use of values from the TEMP reports (Table 1).

Further investigation of 78 heavy thunderstorms in Czechoslovakia from June to August 1973, revealed the dependance of instability indices i_1 to i_4 on the air humidity represented by ß (Figure 2). It is evident that i_2 and i_3 need to rise with respect to i_1 in the area of very dry upper air. Index i_1 may even converge to 0, but if i_2 reaches +3, i_3 + 7, and i_4 + 6 (or similar) then real afternoon thunderstorms may develop rapidly.

Table 1

mb 700 i_1	500 i_2	400 i_3	300 i_4	N	Top Level of CL	
+1	-1	-	-	4	4000 m	Low CL
+1	0	-	-	5	5500	
+	+	0	-	6	7000	High CL
+	+	+	0	7	9000	
+	-	+	+	8	9000	
+	ø	ø	ø	9	10000	

- ≤ -2; + ≥ 1; ø ≥ 4; CL = Convection layer
Instability index i: Temperature difference °C in certain pressure level between the core of the Cu-Cb cloud and the surrounding air.

The curves ß(+2..0..-6) were obtained as mean values of instability indices for groups of actual heavy thunderstorms, developed by given ß value (cases not well documented were excluded). Figure 3 shows the increasing importance of instability compensating the lack of air humidity.

Furthermore, this figure represents the dependance between pressure and temperature as it actually occurs during heavy thunderstorm development under certain conditions of instability and air humidity distribution throughout the convection layer. No other arrangement seems to be appropriate for thunderstorm development. This means that the curves of the Figure 3 correspond to real and systematically varying values of mixing ratio.

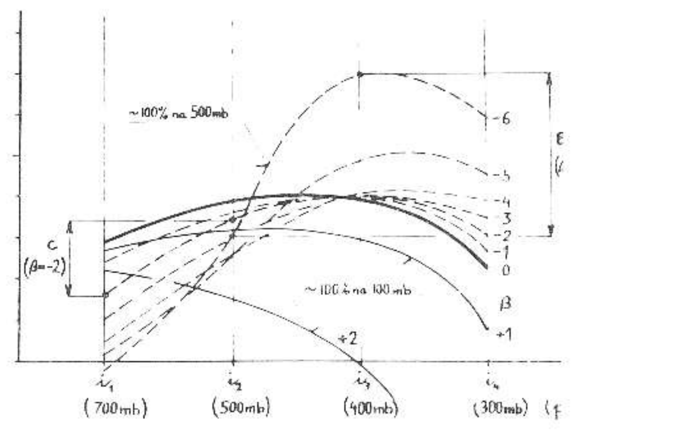

Figure 3: The curves ß derived from actual thunderstorm cases: the falling parts of the curves mean slow cloud development and great mixing ratio, while the rising parts correspond to fast development and reduced mixing.

The limiting mixing ratio values obviously correspond to the extreme curves. Thus, the curves ß=+1,+2 are applicable for maximum mixing ratio of about 100% per 100 mb while the curve ß=-6 represents the minimum ratio of 100% per 500 mb.

Microconvective layer

This conclusion reveals the question of the main mixing area during the Cb development. This has been found to occur just in the active top of any cu-cb cloud in a very thin layer of 5-10 m, where the active mixing of the cloud air with the upper surrounding air is taking place.

The non-adiabatic process within this microconvective layer is the main consumer of the heat energy transported through the core of the cloud to its top. The core upcurrent velocity of 10-30 m/s is rapidly reduced to 1-3 m/s within the microconvective layer. And the propagating velocity of this layer, depending on the heat supply from below, is the growth velocity of the cloud.

Rapidly decreased up-velocity causes horizontal spreading of the fresh mixture at the top of the cu cloud, which forms the uppermost portion of the sides of the cloud, thus isolating the core from the surrounding air.

The action goes on as long as the rising core is bringing the heat supply. The model of Cb cloud corresponding to the above conditions is shown in Figure 4.

Fast and slow development

Thunderstorms of any size may occur, apart from the majority of "normal" ones in two extreme cases:

1. The case of fast development;
2. Slow development with long lasting active cu stage.

The cu stage of Cb development is the time period from first actively towering cu to the first signs of the developing thunderstorm.

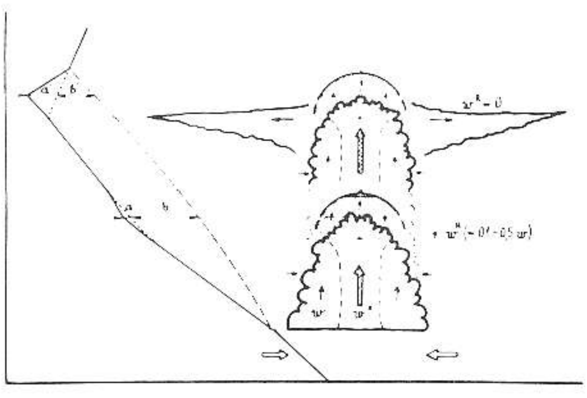

Figure 4: Developing Cu-Cb cloud with main mixing area just on top of it. The heat and water supply from the core of the cloud is compensating for the loss of energy by mixing with dry and cold upper air.

Table 2

i_1	i_2	i_3	i_4	Time Period Cu-Cu hours	N
+4	+3	+2	+1	>6	8
+2	+2	+2	+2	4-6	8
+1	+2	+3	+4	2-4	8
+2	+4	+6	+8	1-2	9

The so called "first interval" of convection after clear mornings is always about the same, but for the first hour of cu appearance only. Further events depend on air humidity and detailed instability actually present throughout the convection layer.

Fast development corresponds to a rising value of instability indiced while slow development is revealed by decreasing values (Table 2). The fast example corresponds to 1-2 hours of cu stage, while the slow one to more than 6 hours, which evidently means good conditions for gliding activities. This can be expected in the case when the upper air humidity is not greater than that corresponding to a temperature deficit of 2° C. When it is $< 1^\circ$, we have to expect long lasting alto-stratus, alto-cumulus, and strato-cumulus continuing as the long lasting decay stage. A temperature deficit near zero in the upper portion of the convection layer causes the decaying clouds to last for hours over a wide area.

CONCLUSION

Analysis of appropriate TEMP reports is still needed for precise forecasting of any type of convection, especially for recognizing two extreme cases mentioned. The fast case permits only very short flights to be made, while the slow one on the contrary offers long flights, with excellent convection over a wide area. The latter seems to provide a relatively rare but real opportunity to cover great distance in a short time period, not yet exploited. The really nice first convection interval is common for both cases and may (without knowledge of actual TEMP) often mislead any organizer of gliding flights.

SUMMARY

Detailed analysis of TEMP reports for thundery days in the Bohemian area have shown correlations of temperature, humidity, instability and mixing ratio, appropriate to the development of strong or heavy thunderstorms. The parameters used were derived from values of TEMP reports. A model of Cu-Cb cloud with mixing area just on the active top is presented.