LOCAL THUNDERCLOUDS – KINEMATICS, PRECIPITATION, PREFERRED OCCURRENCE

J. Reuss, Chur, Switzerland
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Zusammenfassung

Zwei lokale Gewitterwolken traten innerhalb von 5 1/2 Stunden und innerhalb desselben Kreises von ca. 35 km Durchmesser im südlichsten Schwarzwaldgebiet auf. Sie wurden in teilweise größeren Zeitabständen photographiert und später photogrammetrisch ausgewertet. In der fast windstillen Umgebungsluft traten im Umkreis von mindestens 120 km keine weiteren Gewitterwolken auf.

Die Lage der sichtbaren Konturen, besonders des wachsenden Ambosses, wurden photogrammetrisch gemessen. Die Ergebnisse ermöglichen, die Lage des oberen Aufwindstromes und seinen Durchfluß abzuschätzen und diese mit Lage und Menge des Niederschlages zu vergleichen. Diese Ergebnisse werden jenen früherer Auswertungen gegenübergestellt.

Abschließend wird die Gewitterwahrscheinlichkeit von Orten an größeren Gewässern mit jener von Orten abseits von Gewässern verglichen. Der Unterschied zwischen beiden Wahrscheinlichkeiten hängt deutlich von der mittleren Windgeschwindigkeit in Bodennähe ab: Bleibt diese unterhalb 3 m/sec., so steigt die Gewitterwahrscheinlichkeit der 'feuchten' gegenüber jener der 'trockenen' Orte auf das ca. dreifache. Enthalten die 'feuchten' Orte zudem größere Industriegebiete und sind bewaldete Berge in der Nähe, so scheint die Wahrscheinlichkeit für das bevorzugte Auftreten lokaler Gewitter dort auf mindestens das Fünffache zu steigen.

The thunderclouds here investigated represent the rather rare cases of widely isolated cumulonimbi. According to actual precipitation reports, there were no other thunderstorms within a range of at least 120 km, and within ± 1 days.
The first cb, especially its anvil, was photographed towards the north, at intervals, from 13.00 to 15.00 C.E.T., on May 19th, 1975 (Fig. 1A). The properties mainly of this cloud will be analyzed as far as the shape and motion of the anvil permits. A second cb was sighted at the same area, and photographed at 18.000 C.E.T. (Fig. 1B); its position was measured approximately for comparison with that of the first cloud and to local reports.
Since such an isolated cb, especially its anvil, is undisturbed by other clouds, it can be photographed from a remote and fixed terrestrial point for later measurement and evaluation. Combined with

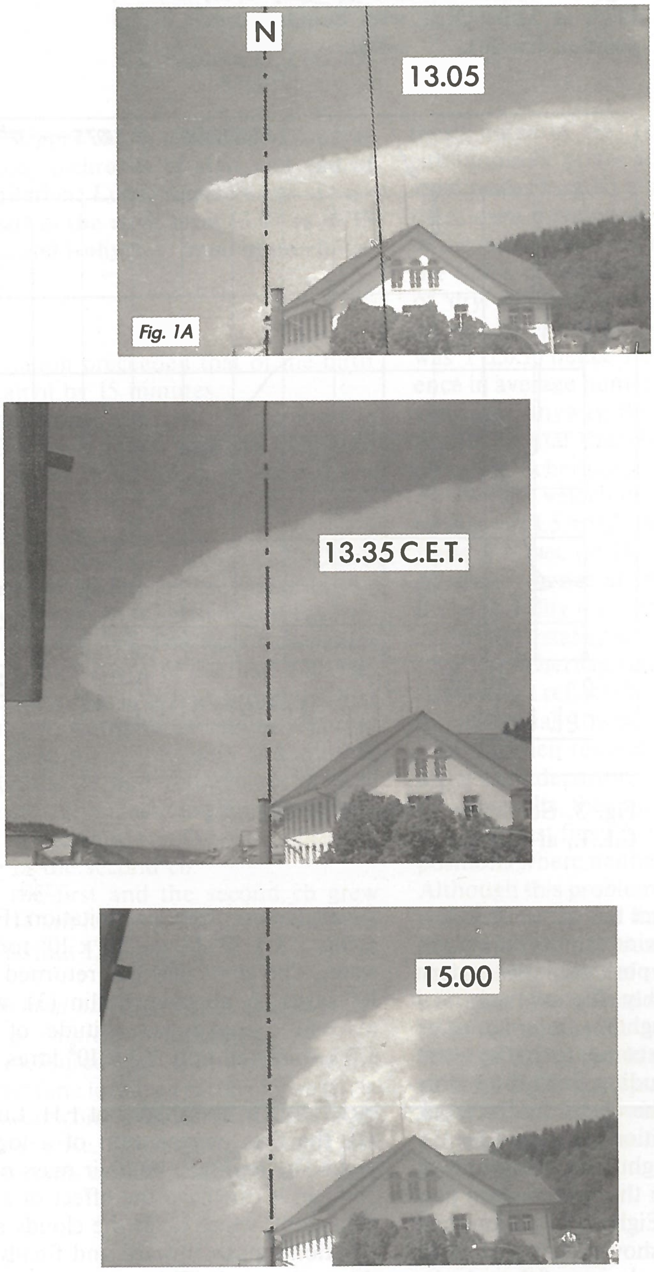

Fig. 1A

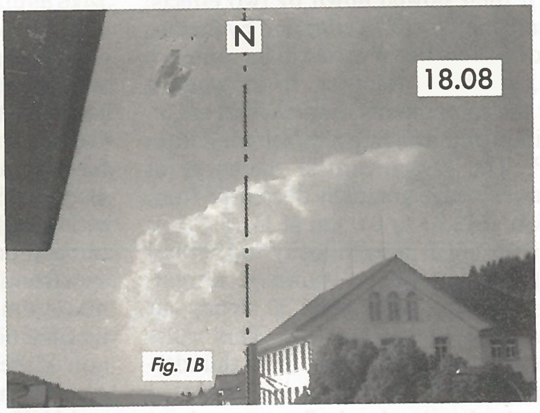

Fig. 1B

earlier results of similar cases, the photographs can then to a certain degree serve for a visual identification of a local cb's properties.

1. The Surface weather chart
of 7.00 C.E.T is rather typical for local thunderstorm occurrence (Fig. 2). The thunderclouds' position near the southern end of a front is marked by a circle. Two High centre of the same baric level of 1025 mb flanked a faint trough; its front had an average temperature difference of only 2°C; it advanced eastward at some 8 m/sec - twice as fast as forecast. At the time of these thunderclouds' occurence the front was some 300 to 400 km east of its position on the chart. The issue of increased occurrence probability as depending on local conditions will be discussed in section 4.

2. The 12.00 C.E.T. sounding of Stuttgart,
140 km north of the clouds' position, yields an average vertical temperature gradient of -0,73.°C/100 m from 900 to 500 mb (Fig. 3). This even exceeds the average of the vertical gradients of 10 other cases of local thundercloud occurrence in that vertical thickness, which was -0,66 ± 0.04°C/100 m (the 0.04 value being the standard deviation of each case; for comparison, 10 cases typical for no thundercloud occurrence yielded an average of -0.52 ± 0.06°C/100 m). The altitude of the tropopause was 11.1 km; it became more pronounced and elevated to 11.3 km towards midnight. To allow for possible inaccuracy, the altitude of the anvil's upper surface to be used for further evaluation will be assumed as 11.5 km; the height above the position of photography resulting as 11.0 km. Since only single photos were taken, this height becomes the base of further computerized photogrammetrical evaluation, which also took account of the earth' curvature.

3. The results of photogrammetric measurements
will be presented and compared with such of earlier cases.
The anvil arose at about 12.55 C.E.T. with an initial radial velocity of some 11 m/sec but it then slowed down by two effects: By lenghtening of its edge and by friction it slowed to some 5 m/sec in its southern part, within 32 minutes. In its western part the components towards west are, in addition, reduced by a 5 m/sec wind from 280°. The mean vertical thickness of the anvil's edge gradually decreased from 1.0 km at 13.03 to 0.6 km at 13.35 C.E.T. With the initial radial velocity and vertical thickness, and with an estimated perimeter of 80 km, we obtain a cloudy air flow of some 0.9 km^3/sec. This value compares well with that of a thundercloud of nearly the same height, reported 1961 (1); its cloudy air flow was about 1.0 km^3/sec. The motion of the western half of the anvil's edge yields an upper virtual centre of updraught (marked by a cross in Fig. 4). Since this centre, together with the general wind cannot in full account for the edge position in the eastern visible part, a roughly elliptical horizontal form of the updraught maximum must be assumed. This also compares to the result of 1961 (2). Concluding from the visible western edge of the cb below the anvil, and from the position estimated by the maximum updraught, the maximum of precipitation lay in the nothwestern portion of the cloud. Eight local stations had reported hail and showers between 12.45 and 14.40 C.E.T.; only one of them had a shower between 18.00 and 18.40 - from the second cb - but without measurable precipitation.

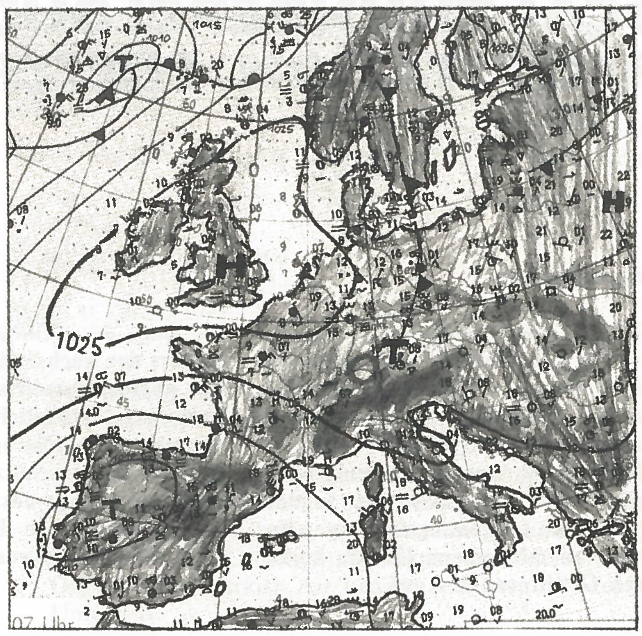

Fig. 2. Surface weather on May 19th, 1975, at 7.00 C.E.T., with thunderstorm position (circle).

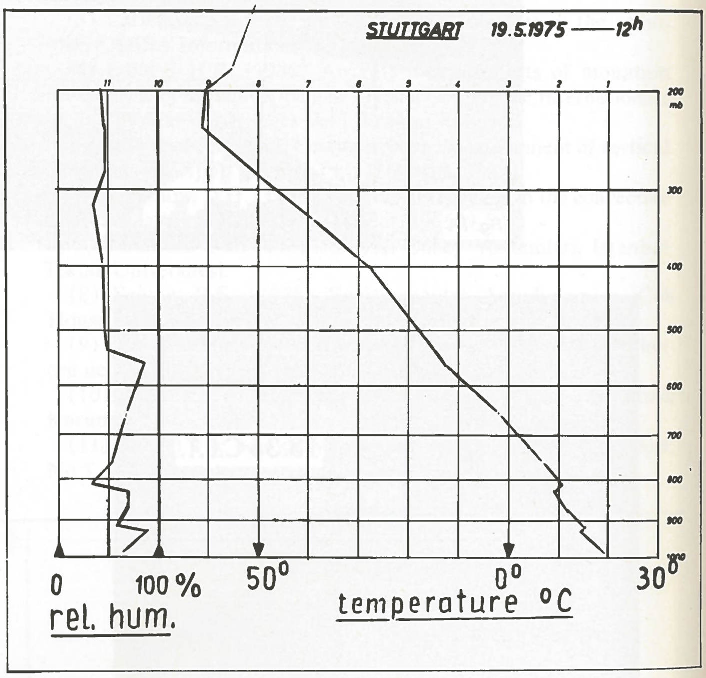

Fig. 3. Sounding of May 19th, 1975, 12 C.E.T., at Stuttgart.

A calculation of the precipitation (Fig. 4) yields 2.3 x 10^9 litres (2.3 x 10^6 tons) of water. The cb of 1961 had returned 3.5 x 10^9 litres. A cb over Berlin (3), which reached a maximum altitude of only 5.7 km, rained only 2.4 x 10^8 litres.

According to the theory of F.H. Ludlam (1), the first precipitation of a local cb yields, by drying, a cold air mass on the surface; it can have the effect of a local cold front, which gives the cloudy air an additional push upward and finally produces the anvil. This makes it plausible that the anvil arose at 12.55, some 25 minutes after the first precipition occurred. By the cb of comparison (2), the start of

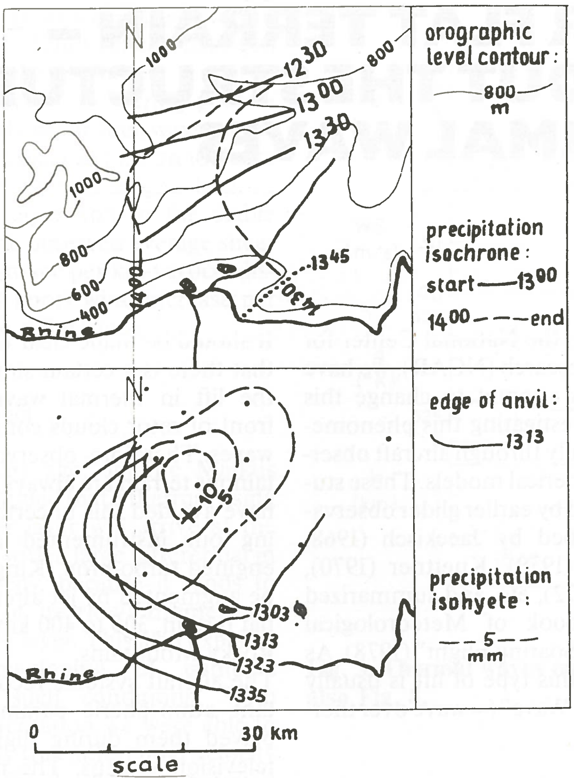

Fig. 4. Upper chart: Contours of orography and isochrones of start and end of precipitation. Lower chart: Edge of visible part of the anvil form 13.03 to 13.35 C.E.T., and isohyetes [mm] of precipitation.

precipitation preceeded that of the birth of its anvil by 15 minutes.

The isochrones in Fig. 4 also support the plausible assumption that the local cold front moves downhill, as far as it is not influenced otherwise by a meso-scale general wind.

The first cb decayed at about 15.20 C.E.T., its last rain had been observed at 14.45. No cloud was observed there until shortly before 17.50 C.E.T. The second cb was located some 5 km W of the first; it had no pronounced anvil. While during the first cb's activity seven local stations reported 'thunderstorm at the spot', and another 10 reported 'remote thunderstorm', only one local station recorded 'faint thunderstorm at the spot' for the time of occurrence of the second cb.

Both the first and the second cb grew some 14 km north of the industrial town of Waldshut-Tiengen.

4. The local probability of preferred occurrence of isolated thunderstorms.

Five measured local thunderclouds, and another nine localized merely by observation, were compared as to their positions of occurrence. These measurements and observations clearly confirmed the hypothesis noted in 1961 (2), that in calm air cumulonimbi prefer to grow over industrial towns located close to water. Since there were elevated woods nearby in 86% of the cases, these obviously still increase the ratios of probabilities of 'humid' and of 'dry' stations, $\varphi = \psi h/\psi d$:

At velocities 7 m/sec or more, the ratio φ was 1 ± 0.1; hence no significant difference in average humidity exists. (At these velocities, anyway, the Wichmann-statistics for frontal thunderstorms would replace the Scherhag statistics.)

At average velocities near 3 m/sec, the ratio φ was 1.5 ± 0.2. Between averages of 1 and 2 m/sec (at 14 days), the ratio φ is 2.7 ± 0.3; hence at the 'humid' stations the probability is roughly three times that at the 'dry' stations.

Like the Scherhag-statistics itself, this result doesn't reflect the additional increase by industrial towns and wooded hills – and/or their respective shares in releasing a thunderstorm. Estimating by our sparse results, they increase the probability to at least five times – as compared to positions where neither of the three exist. Although this problem is not new, further research along this line appears promising. Another question is to what degree the present stage of air pollution in the northern hemisphere may alter the conditions of release. It seems a good idea both to apply the hitherto-obtained results for flight concepts and to add further observation detail which may make the probability function more differentiated and precise.

In order to determine the relative probability for a strictly local region, we chose six 'dry' stations with no considerable water nearby; and six 'humid' stations close to lakes or rivers. The stations of both categories are well spread over West Germany, and at about equal altitudes, with the spread of the latter small (364 ± 67 m and 365 ± 140 m a.s.l., respectively). For 47 days of moderate winds, the surface wind, the absolute humidity and the resulting probability were analysed statistically. The mean values for the 'dry' and the 'humid' stations were calculated, with the probability of occurrence (if the two other conditions are present).

For a theoretical verification and eventual extension, it seemed sensible to start upon the Scherhag statistics (4). Scherhag had stated a connection between surface absolute humidity and the relative thunderstorm frequency; he derived an empirical probability function for local thunderstorm occurrence (for Central European conditions, at least). While this probability ψ practically equals 0 up to an absolute humidity of 8 mb (moist pressure) it becomes practically 1 from 19 mb upward.

References:

(1) *F.H. Ludlam;* notes of a lecture at Darmstadt, 1961

(2) *J. Reuss:* Ein Gewitter bei Windstille; Beitr. Phys. Atmosph. 34<19 259–273

(3) *J. Reuss:* Stereo Measurement of Thundercloud Kinematics; Aero Revue 52 (1977), 48–51