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EVALUATION OF PHOTOGRAMMETRIC FLIGHT UNDER ICING CONDITIONS OF 23 MARCH 1978

Werner Fuchs and Josef Kaluza

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16. Abstract
In a double passage through a route laid out in a stagnation zone of the Bavarian forest, it was found that the stagnation and attendant elevation increases the danger of icing. Conversely, it turned out that formation of precipitation reduces the icing intensity. A comparison of both factors showed: the reduction of ice formation through precipitation equals the increase due to stagnation, or even exceeds it.

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EVALUATION OF PHOTOGRAMMETRIC FLIGHTS UNDER ICING CONDITIONS OF 23 MARCH 1978

Werner Fuchs and Josef Kaluza

Foreword /1*

In the report of the Geophysical Advisory Service of the Army, No. 23 titled: "Measurement, presentation and evaluation of meteorologic icing parameters" [1], the evaluation of photogrammetric flights with a Do 28 under icing conditions was reported. The objective is to bring the measured meteorologic parameters into harmony with the documents available from the "Routine Service." An initial attempt with the measured results of 23 March 1978 showed that this goal can be attained. In order that the results be available to all who must make predictions of icing zones, they are summarized in this report.

The publication of weather charts will follow with the approval of the German Weather Service.

Summary: /2

In a double passage through a route laid out in a stagnation zone of the Bavarian forest, it was found that the stagnation and attendant elevation increases the danger of icing. Conversely, it turned out that formation of precipitation reduces the icing intensity. A comparison of both factors showed: the reduction of ice formation through precipitation equals the increase due to stagnation, or even exceeds it.

In future flights in icing zones, the influence of other factors like:

- bending of the stream
- vorticity advection and
- lability

will be studied and compared.

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*Numbers in the margin indicate pagination in the foreign text.

1. Weather Situation of 23 March 1978, 0000 hours to 1200 hours /3

On this day, a low-pressure area with its offshoots determined the large weather situation over Western and Central Europe. The ground low at 0000 hours had its center South of Iceland (figure 1). Its fronts were analyzed by the German Weather Service as follows:

- occlusion: Iceland-North Sea;
- occlusion point: 53°N, 05°E;
- warm front: Line Brussels - Central Massif - Moulins;
- cold front: Line Rotterdam - Tours - La Rochelle.

The absolute topography of 850 mbar and 700 mbar (figures 2 and 3) confirm the position of the fronts by the location of their isothermal lines. The profile of their isohypses shows that the frontal system is moving Eastward at about 25 knots. While doing so, it became more occluded (figures 4, 5 and 6) and lay on a line from Copenhagen - Magdeburg - Regensburg - Lake Constance by 1200 hours.

At air temperatures at 2 m height of 0°C to + 7°C, rain, snow-rain and snow, or rain showers and snow-rain showers were reported. The band of precipitation ran nearly parallel to the front system.

An evaluation of the radiosonde probes from Hamsby (03496), Trappes (07145), Stuttgart (10739) and Munich (10868) and of Idar-Oberstein (10618) and Gaermersdorf (10771) (see figures 7, 8 and 9), showed that the precipitation in the area of the warm front is due to upslide motion, and in the area of the cold front, it is due to lability.

2. Icing Prediction /4

According to [1], section 1.4 "Sequence of Flight," photogrammetric flights were performed by Proving Ground 61 of the Army, when the Geophysical Advisory Service predicts regions with icing conditions. The rules summarized in [2], chapter 6, govern these flights.

The following current high-elevation weather charts, radioprobe measurements (Temps) and ground weather charts were available at about 0600 hours for the predicted time frame 0730-1130 hours.

- ground weather chart 1:15 Million 0000 hours (figure 1), and 1:5 Million 0300 hours (figure 4);
- Temp Munich (10868), Stuttgart (10739), Trappes (07145) and Hemsby (03496) at 0000 hours (figure 7);
- absolute topography 850 and 700 mbar (figre 2 and 3) of 0000 hours [2] makes a distinction between predictions of icing intensity:
  - due to high-elevation weather data (rules 1 and 2) and
  - due to ground weather data (rules 3 to 9).

Here, rule 1 excludes ice-free regions. They are positioned as follows (figure 7):

- Temp Munich 0000 hours: below 800 mbar;
- Temp Stuttgart 0000 hours: below 900 mbar and above 620 mbar;
- Temp Trappes 0000 hours: below 800 mbar.

Rule 2c concerns regions with heavy cumulus sources. This is the case in the region of the cold front, represented by the Temp Trappes 0000 hours:

- between 0°-limit at 825 mbar to the tops of the sources at 620 mbar, "slight icing" is predicted.

Of rules 3 to 9, rule 5 pertains to warm fronts: /5

- between 0°-limits (Temp Munich 0000 hours at 900 mbar) and -15°C (Temp Munich and Stuttgart 0000 hours at 600-650 mbar), "slight icing" is predicted. This applies to the region within the clouds up to 300 miles (about 500 km) in front of a warm front.

A prediction of the type of ice is obtained from rules 10, 11 and 12.

- rule 10: "Coarse ice" prediction when the temperatures in ... stratus clouds lie between -1° and -15°C;
- rule 11: "Clear ice formation" is predicted when the temperatures in cumulus clouds...lie between 0° and -8°;
- rule 12: "Coarse ice and clear ice formation, mixed" is predicted when the temperatures in cumulus clouds lie between -9° and -15°C.

Thus, together with a predicted shift of the fronts for 0900 hours, the icing regions and zones of figures 10 and 11 result.

Similar results are obtained when using the rules of the US Air Weather Service, as presented in [3]:

- in the region up to 500 km in front of a warm front and in stratus clouds between -1° and -15°C, it is recommended to predict "slight, rough ice;"
- in the region up to 160 km behind a cold front and in sources between 0° to -8°C, it is recommended to predict "moderate clear ice;" between -9° and -15°C, it is recommended to predict "moderate, mixed ice."

The German Weather Service predicted for 1200 hours "moderate icing" in the frontal region in its main weather charts (figure 12).

The Geophysical Advisory Center, South, predicted on its tactical region chart No. 9 for 0900 hours "moderate icing from 3000 ft. mean sea level (MSL) to flight level (FL) 120" over South Germany (figure 13). /6

The advisor of the Geophysical Advisory Center of Proving Ground 61 predicted "light to moderate coarse ice between 3000 ft. MSL and FL 130" for the time segment from 0730 to 1130 hours.

Specifically for the photogrammetry aircraft, a "Flight Forecast Cross Section" was produced (figure 14) with the prediction "slight to moderate icing above 3000 ft MSL."

3. Description of Flights by Do 28 and Bo 125 /7

The measuring aircraft Do 28 took off in Manching (EDSI) at 0812 hours. The flight led first Eastward to Straubing (STB), then Northwest to Hemau (figure 15). From there, the aircraft flew the same route back to Manching, where it landed at 0932 hours. This means that the same route was observed at two different times.

The following notations of observations were made on board the aircraft:

a) Record of Flight Engineer

0812 hours: take off in EDSI, direction STB;

0821 hours, FL 100 reached, stabilized, beginning "light to moderate icing" at FL 90;

0823 hours: 20 NM East of Ingolstadt (IGL);

0829 hours: descent to FL 95, icing continues;

0832 hours: over STB, course change to direction Allersberg (ALB), icing continues;

0840 hours: end of icing, snowfall observed;

0844 hours: slight icing is observed;

0849 hours: end of icing on exit from the clouds;

0852 hours: 24 NM from Allersberg (ALB), about Hemau, course change by 180 degrees;

0853 hours: re-entry to clouds, brief icing;

0855 hours: snowfall observed; no ice;

0900 hours: ascent to FL 100, continued snowfall, but no ice;

0905 hours: above STB, course change toward IGL, ascent to FL 110, the top cloud layer is left below, thus;

0908 hours: descent to FL 100 initiated;

0910 hours: FL 100 reached, brief icing;

0912 hours: exit from clouds;

0916 hours: descent to landing in EDSI begun;

0932 hours: landing at EDSI.

Figure 16 was constructed from this record.

b) Measurement Record of the Recording Instruments Described in [1] (Figures 12 and 18) /8

- vibration frequency detector made by Rosemount Engineering Co., icing degree: steep rise indicated high degree of icing. After every heating phase, return to baseline. Thickness of ice charge: if the ice charge has exceeded a certain value, then the unit triggers an ice warning signal. Simultaneously, the ice charge at the detector is melted away by heating.

- scattered light probe by DFVLR for visibility measurement. Decreasing visibility is plotted upward.

c) Temperature Profile on Ascent of the Aircraft Do 28 is Measured (Figure 12)

At this point, it is appropriate to report that between 0805 hours and 0923 hours, a helicopter Bo 105 of Army Proving Ground 61 flew from Manching (EDSI) over Ingolstadt (IGL) to Straubing (STB) and back. Meteorologic observations were also performed, since the flight had been performed to check the roto-blade icing system.

The following notations of observations on board the Bo 105 exist:

a) Pilot's Record

0805 hours: take off from EDSI, ascent;

0817 hours: about 6 NM east of IGL, entrance into clouds at FL 70;

0818 hours: ascent to FL 80, course direction STB;

0834 hours: ascent to FL 90;

0836 hours: course change above STB by 180 degrees, direction IGL;

0853 hours: engine failure 22 NM east of IGL at FL 90 at 80 kn indicated air speed (IAS), -6°C measured outside temperature, attempted abort, descent;

0923 hours: landing at EDSI.

[One line illegible]

Notable ice charge was not observed. However, on one surface about 0.5 m^2 around the stagnation point around the cabin, a snow layer collected and ever-larger pieces of this continued to break off. /9

b) Temperature Profile Measured on Ascent of Helicopter Bo 105 (Figure 21)

4. Comparison of Prediction with Observations /10

The illustrations (figure 16 to 19) show that the icing intensity during the flight changes with time and place, whereas the icing prediction gives only lump-sum intensities for very large regions and zones.

If we compare:

For 0900 hours in figure 10, light icing was predicted above the zero degree limit at a 500 km-wide strip in front of the warm front. The lower limit of the icing zone should increase to the east (figure 11).

We observed (figure 16):

- increase in icing when flying in the direction of Straubing (STB);
- decrease in icing when flying in the direction of Allersberg (ALB);
- interruption of icing on snowfall;
- changed icing intensity on return flight.

5. Influences on the Icing Intensity /11

In the technical reports, series I, No. 55, H. Baumgaertner writes in the introduction of his report entitled "The Prediction of Aircraft Icing" [4]: "Severe ice formation on the aircraft has two causes:

1. The outer surface of the aircraft must be cooler than 0°C.
2. Subcooled water droplets must be present."

This principle means that the parameter of liquid water content must definitely be taken into consideration on the icing of an aircraft (see [2], chapter 3, III). The reason for changed icing intensity in an icing region or icing zone must therefore be due to change in one of these parameters.

Now how can the liquid water content be changed?

Water vapor in a cloud can condense into droplets through an increase in elevation, by a decrease in elevation, droplets can vaporize again. Elevation is caused by:

a) encounter with warm front;
b) stagnation against mountains;
c) lability;
d) cycloncal bending of the jet-stream;
e) positive vorticity advection;
f) coastal effects.

Depression is caused by:
g) lee effects of mountains;
h) anticyclonal bending of the jet-stream;
i) negative vorticity advection.

To determine the factors which could have caused a local or temporal differing elevation or depression of the warm front of 23 March 1978 over South Germany, we consider the weather situation of this day between 0600 and 1200 hours.

The absolute topography 850 and 700 mbar of 0600 and 1200 hours (figures 22 to 25) shows a uniform stream of 30 to 40 kn. No tough axis is seen. Shear and thus cohesive, positive vorticity advection did not occur over South Germany. Thus, the factors c), e), f), h) and i) are eliminated. Factor c), lability, is described in the region of the warm front by the temperatures (figure 19) recorded by the Do 28 and by the Temp Gaermersdorf (10771) from 0600 hours (figure 9). In addition, the temperature measurements of the Bo 105 (figure 21) are available. All 3 measurements indicate stable to indifferent layering in the warm front. /12

So the following factors remain;
b) elevation due to stagnation;
g) depression in the lee of a mountain.

Between 0600 and 1200 hours, a southwest stream was blowing against the Bavarian forest (figures 6, 22 to 25). The resulting stagnation and lee regions were taken from the Luv- and Lee-charts for SW stream (AWGeophys 1973, Anf. listing Sk - 20-K-LL-SW) and are entered in figure 15. From this figure, the limits of the stagnation and lee regions are projected into figures 16 to 18. Now it would be pure chance if these limits were to agree exactly with the beginning and end of icing.

But the increase in icing intensity to Straubing (STB) and the decrease to Hemau agrees surprisingly well with the change in the Luv- and Lee-intensities.

In order to explain the completely different icing intensity on the return from Hemau via Straubing (STB) to Manching (EDSI), we must find other factors which can withdraw liquid water from the "sliding cloud" system. Here, we are assuming that in the time from 0821 to 0912 hours, the air mass flowing toward the Bavarian forest did not change significantly, neither in composition nor in direction.

Now the flight evaluation shows that in zones with snowfall, the /13
icing intensity decreases. This fact indicates that liquid water was taken from the cloud by the factor

k) generation of precipitation due to formation of snow (Wegener-Findeisen-Bergeron Theory). This would explain why the icing between Straubing (STB) and Hemau is interrupted briefly during a simultaneous snowfall.

Probably, in the short time between 0840 hours, end of icing, snowfall observed (Straubing to Hemau), and 0855 hours, snowfall observed, no ice (Hemau to Straubing), the formation of precipitation had expanded greatly in size. This could be confirmed only by a complicated analysis of all rainfall registrations in this region. The METAR notations of the Straubing (EDPS) airfield (see appendix 1) clearly show an increase in snowfall intensity to 0900 hours with a maximum between 0900 and 1000 hours.

If we compare the factor b) with k), then in the present case, the precipitation formation equals the stagnation effect and decreases the icing intensity. This contradicts rule 4 on page 54 in [2]. Accordingly, a statement on icing in stagnation situations and front clouding should be independent of precipitation. This rule will thus be checked in the evaluation of additional icing flights.

6. Evaluation of the Record of the Bo 105 /14

The pilot reports in his record:

0853 hours: engine failure 22 NM east of Ingolstadt (IGL) at FL 90 at 80 kn;

IAS, -6°C measured outside temperature;

attempted abort, descent.

After the landing at 0923 hours in Manching (EDSI), no fault could be found in the failed engine. From this it was concluded: a sufficiently large amount of snow got into the engine to cause its failure.

This means: for the Do 28 photogrammetric flight, the formation of precipitation decreased the icing intensity. The snow present at FL 70 increases the danger for the aircraft Bo 105.

7. Results /15

The icing theory obtained from the photogrammetric flights is illustrated in figure 26.

A depression between two elevations and a jet-stream above this is seen. We can now distinguish 4 regions:

Region I: lee behind mountain 1;

Region II: undisturbed region;

Region III: stagnation in front of mountain 2;

Region IV: precipitation region.

A warm front is embedded in the jet stream.

The prediction rules show; "slight icing in the warm front region." This statement is now changed as follows;

Region I: no icing;

Region II: slight icing;

Region III: moderate icing;
Region IV: light icing.

Let us summarize:

The icing rules described in [2] and [3] have not proven to be incorrect in the case under study here. They only have deficiencies in that they do not take local peculiarities into account. The icing degree V worked out by means of the icing rules must therefore be modified from place to place by an amount V_s. V_s is composed of a series of summands

$$\overline{V_s} = a \cdot K + b \cdot VA + c \cdot S + d \cdot L + e \cdot KS + f \cdot P + g \cdot LE$$

Legend:

K = bending of the stream between 850 and 700 mbar,

VA = vorticity advection,

S = stagnation against mountains,

L = lability,

KS = coastal stagnation,

P = precipitation formation, and

LE = lee behind mountains.

This list of summands is surely not complete, but those listed /16 are considered to be the most important. The coefficients 'a' to 'g' are the "weights" of the summands.

Through this evaluation, an initial estimation of the weights for stagnation and precipitation formation can be given:

$$c \cdot S \text{ is about equal to } -f \cdot P$$

and both modify V by about one degree of intensity each.

8. Conclusion

Due to the general icing rules as are described for instance in [2] and [3], the icing in certain regions and zones can be estimated only in a lump-sum manner. Frequent overestimations make the icing prediction unbelievable by the user, yet underestimated icing is a hazard to flight safety. Therefore, further measurement flights under icing conditions will be evaluated. We hope to be able to obtain information on the weights and other summands and finally, to improve the prediction methods.

Mr. Uwira graciously made his documents available to us on the flight of the Do 28 and Bo 105, together with numerous valuable suggestions. The record of the flight of the Bo 105 helicopter was provided by Mr. Kus. The German Weather Service aided with the copies of original weather charts. The geophysical advisory center of Army Air-Wing 205 in Mitterharthausen sent us appendix 1.

Our sincere gratitude is due all the above.

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2. "Icing of aircraft and its prediction," Pamphlet 2, 2nd improved edition, AWGeophys Traben-Trarback, 1976.

3. "Icing Prediction," from: Objektive lokale Beratungshilfen Betriebsunterlagen fuer den Geophys BCBw No. 9, AWGeophys Traben-Trarbach, 1979.

4. Baumgaertner, Hans, "The prediction of aircraft icing," Tech. Report, Series I, No. 55 (1961), 46 pages.

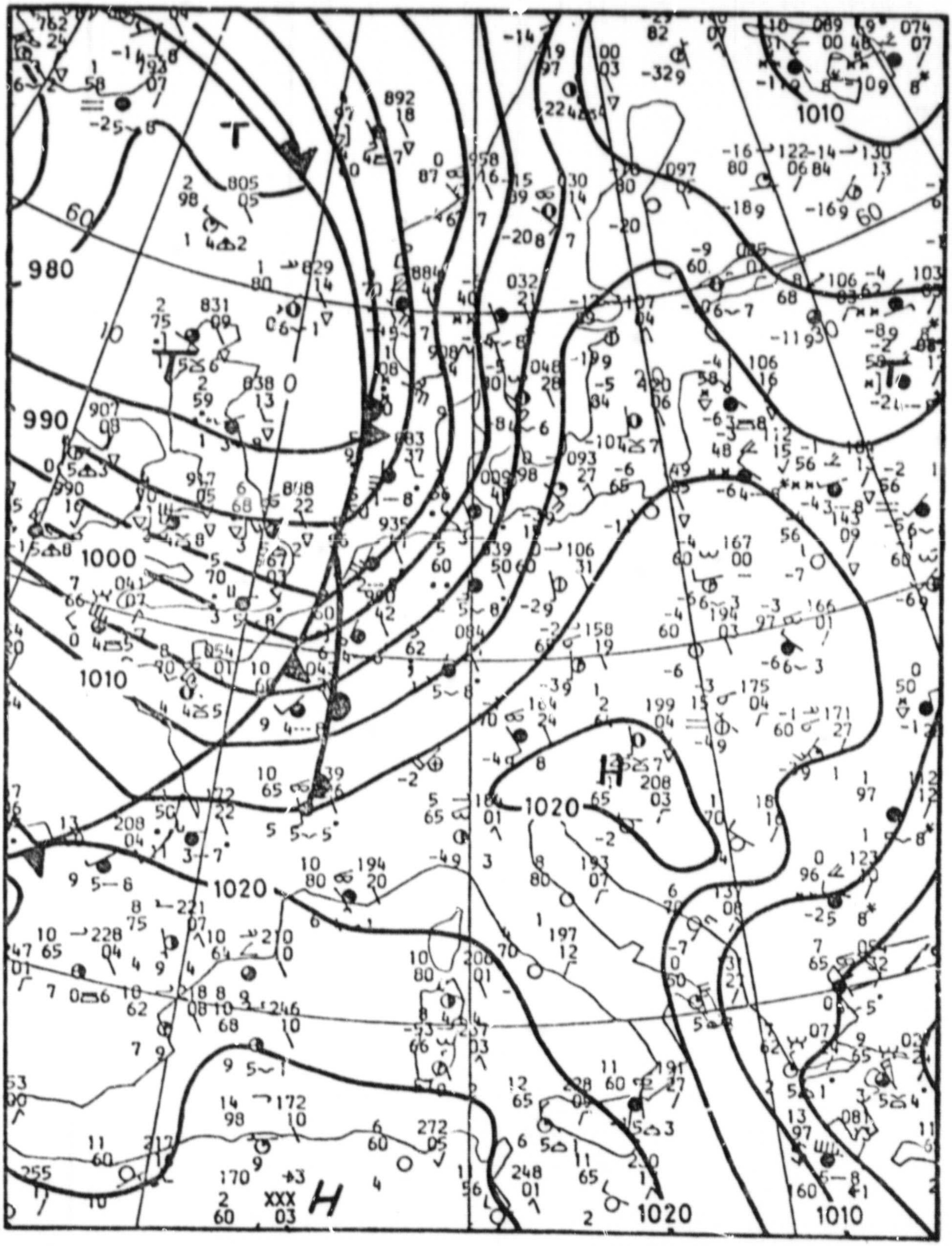

Figure 1. Analysis of ground weather chart of 23 March 1978 at 0000 hours.

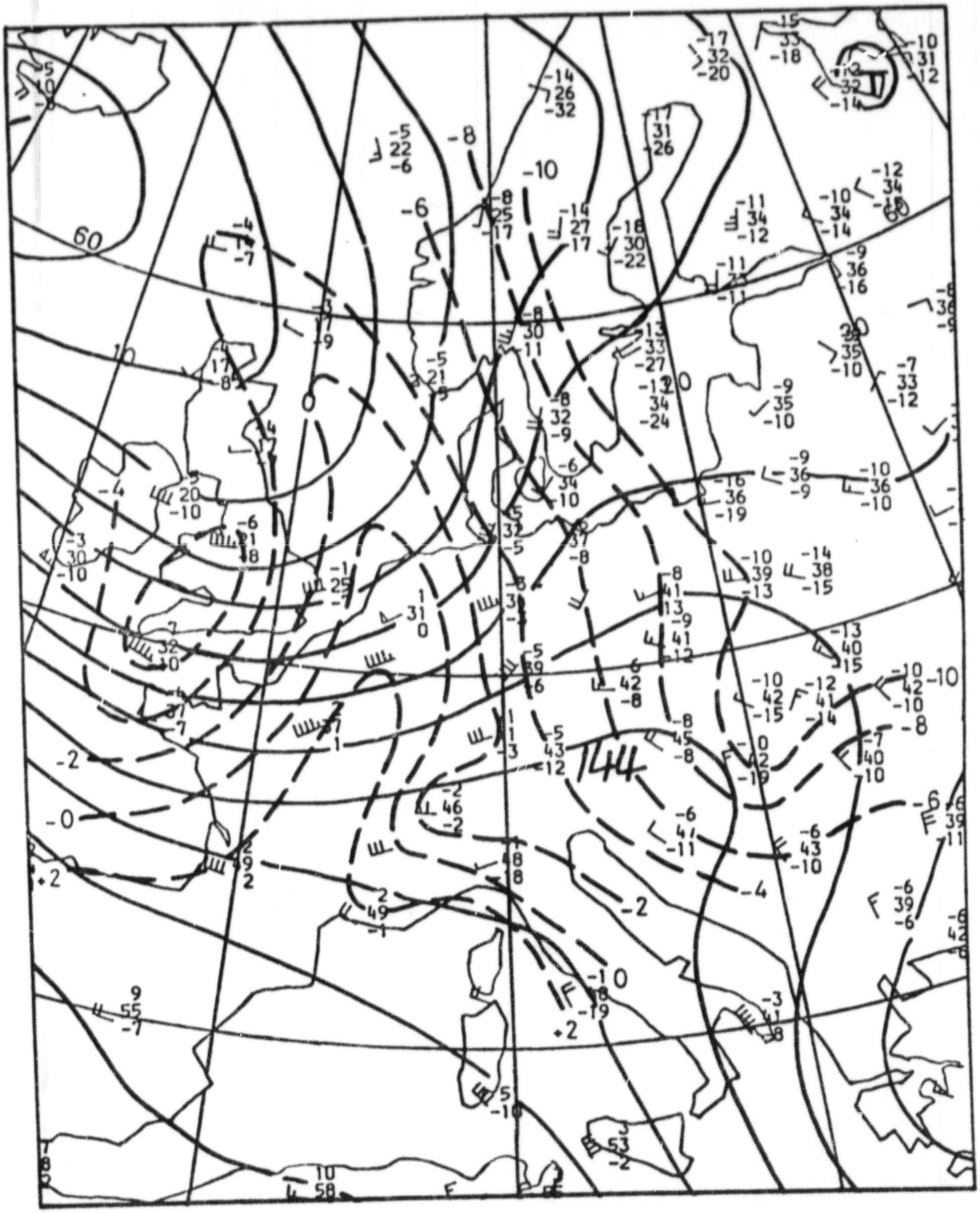

Figure 2. Absolute topography 700 mbar of 23 March 1978 at 0000 hours. Spacing of isohypses 4 geopotential decameter, spacing of isotherms 2°C.

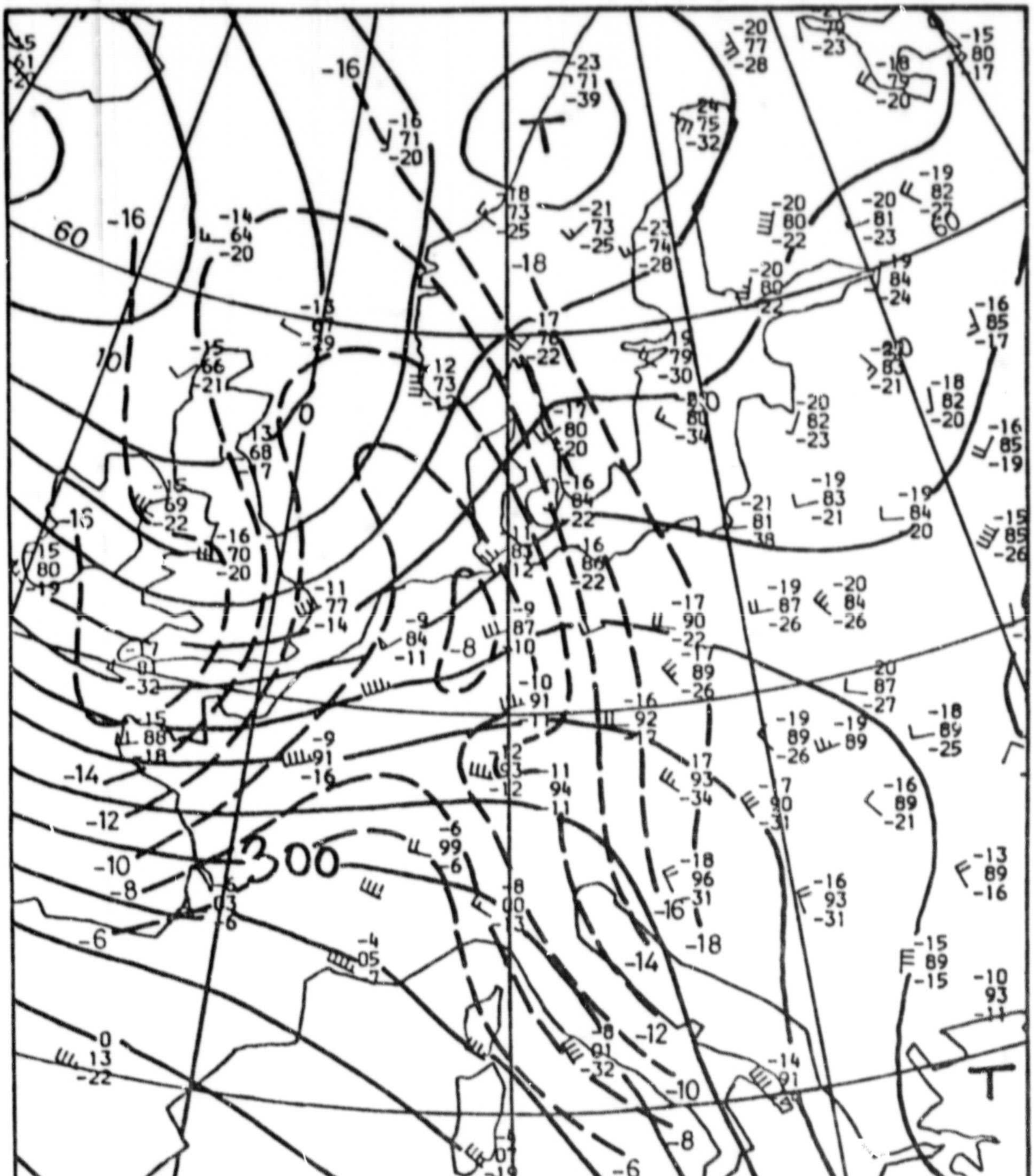

Figure 3. Absolute topography 700 mbar of 23 March 1980 at 0000 hours. Spacing of isohypses 4 geopotential decameters, spacing of isotherms 2°C.

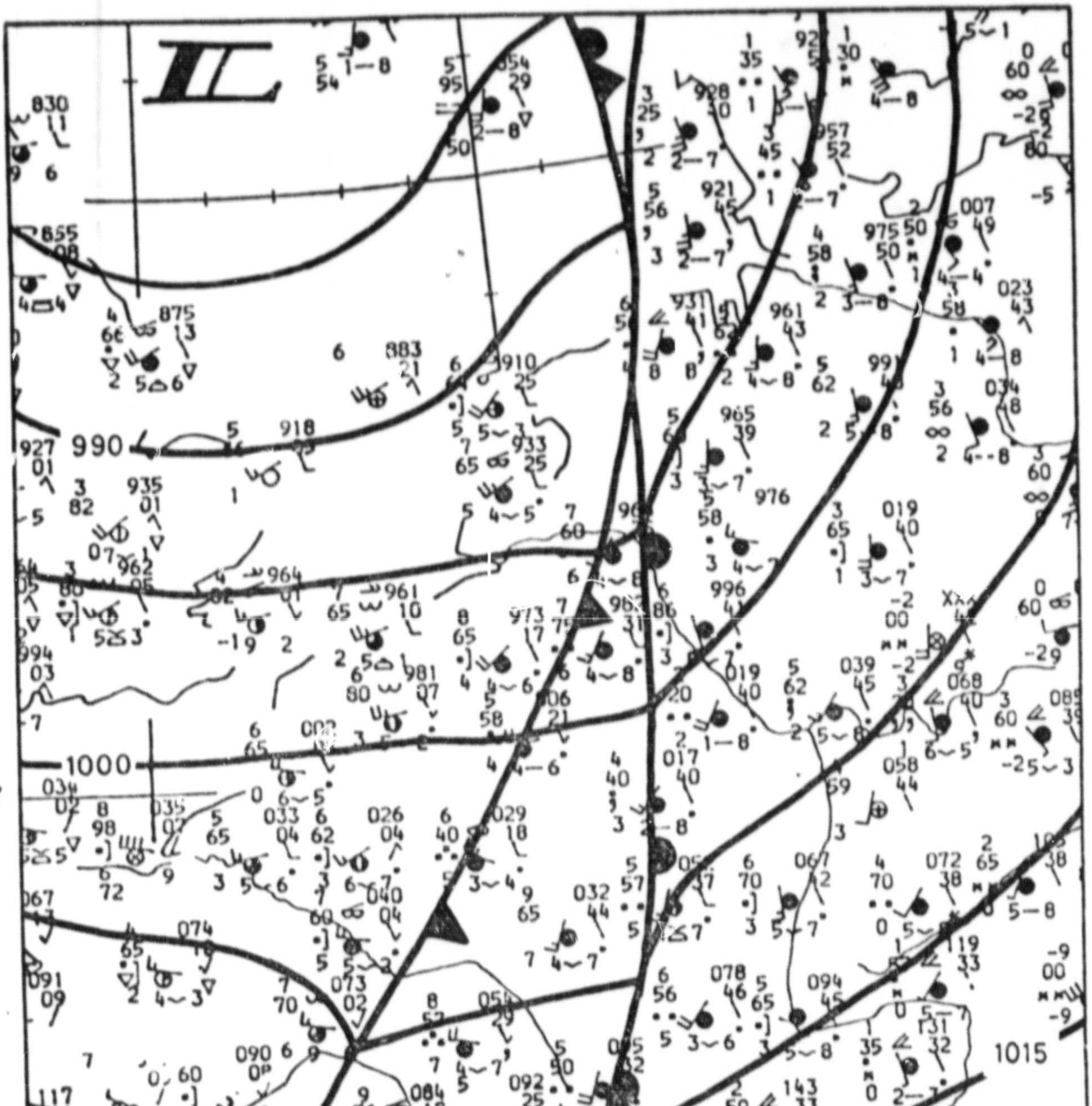

Figure 4. Analysis of ground weather chart of 23 March 1978, at 0300 hours.

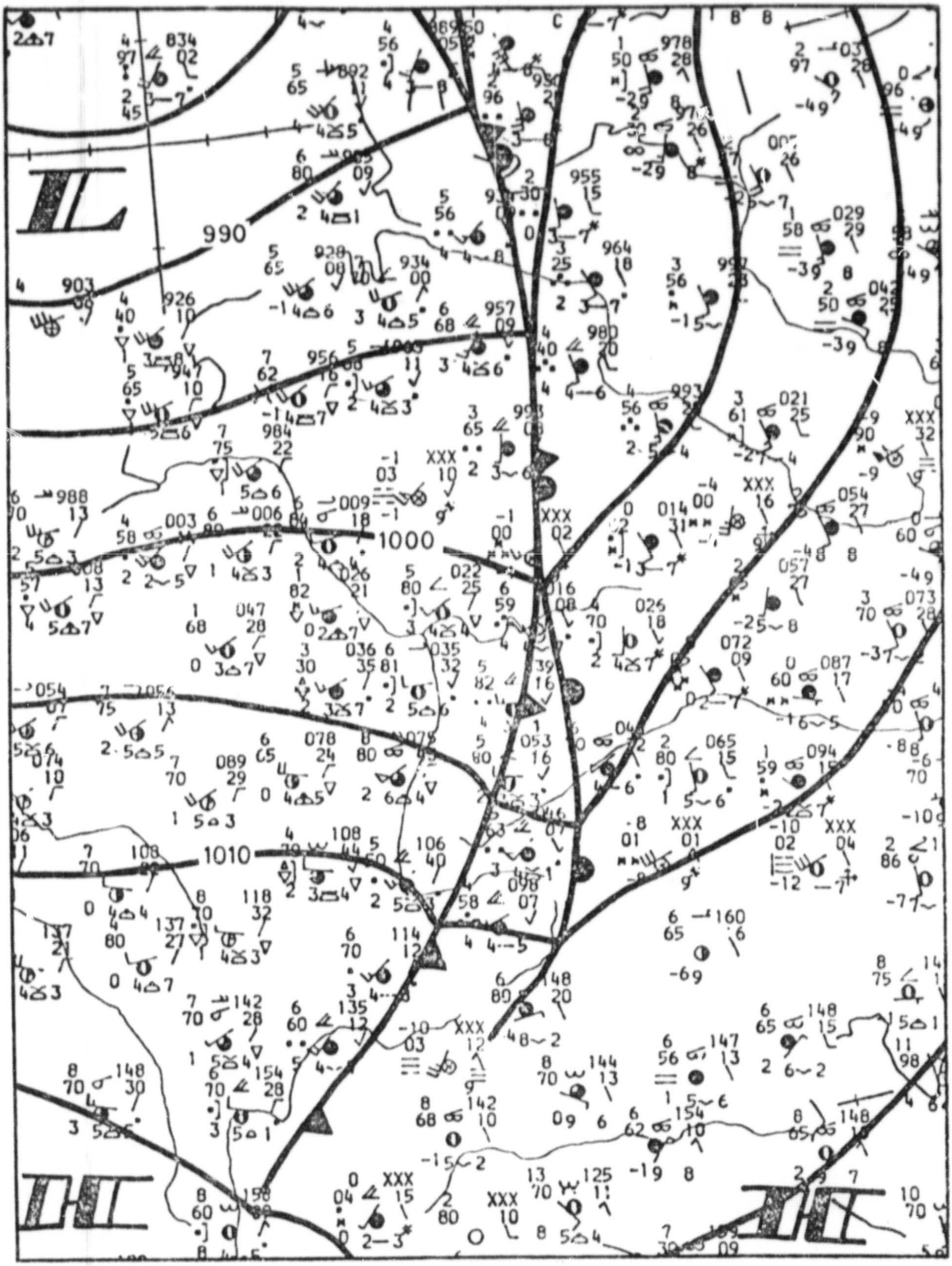

Figure 5. Analysis of ground weather chart of 23 March 1978 at 0900 hours.

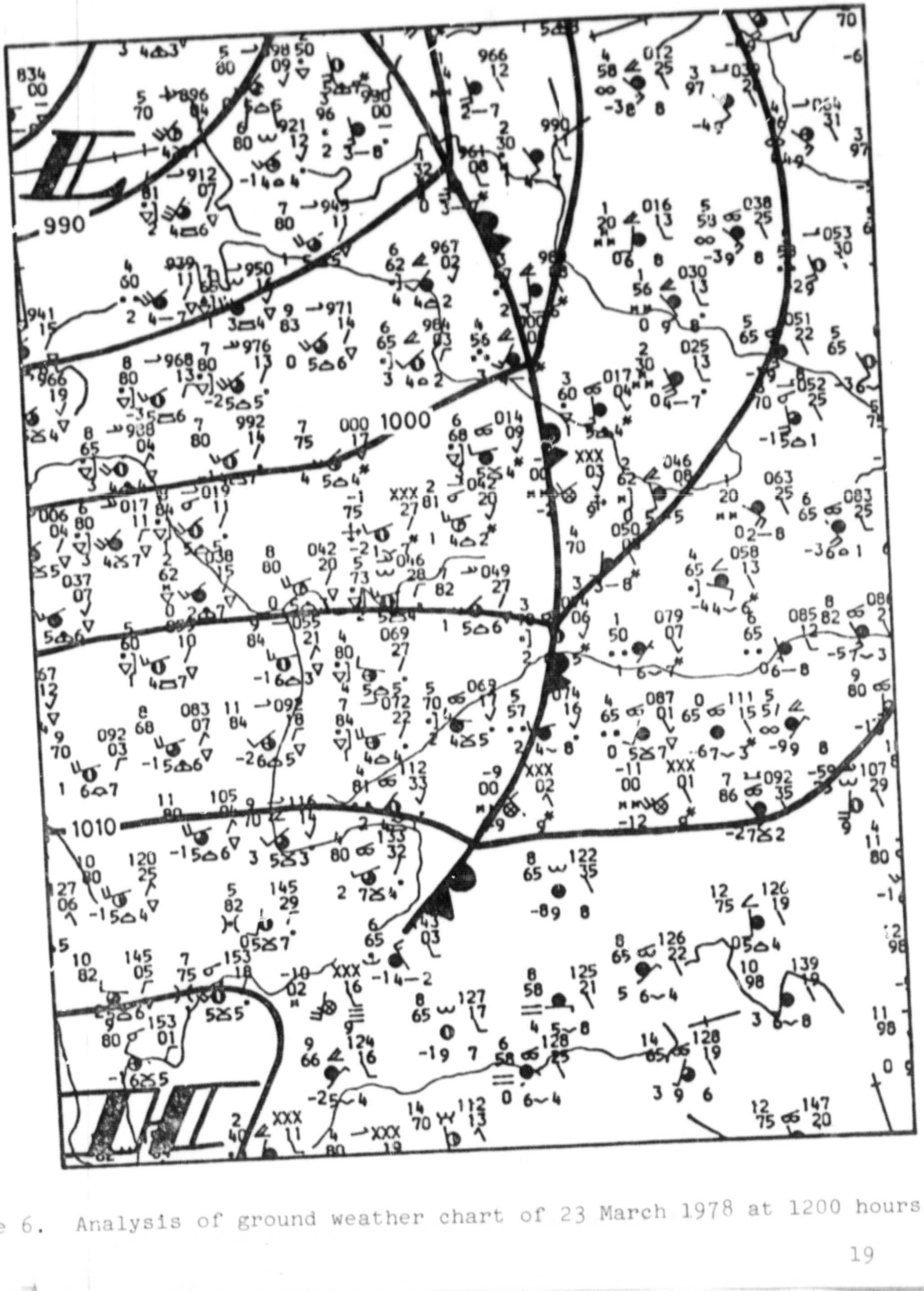

Figure 6. Analysis of ground weather chart of 23 March 1978 at 1200 hours.

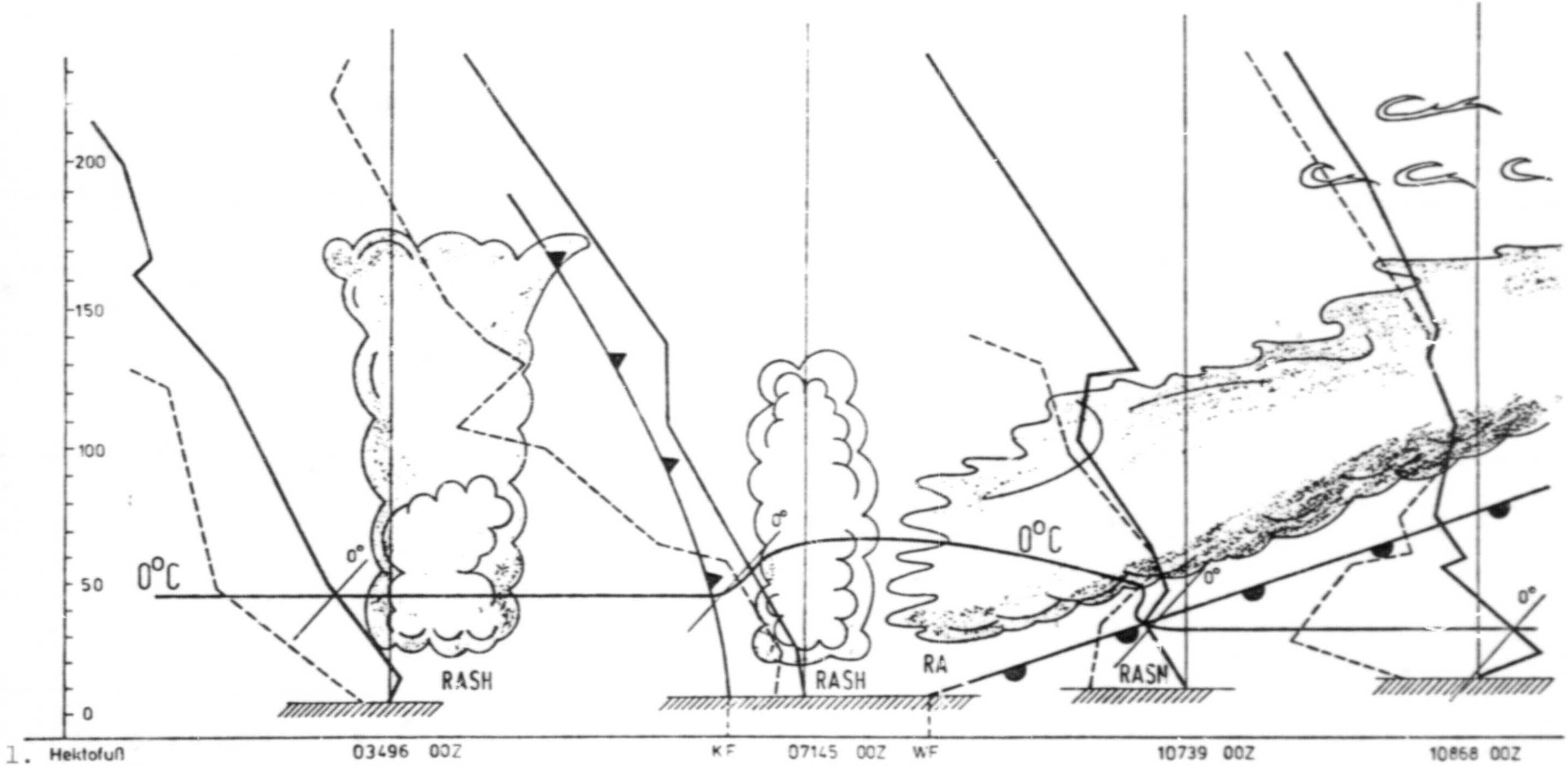

Figure 7. Cross-section through the front system of 23 March 1978 at 0000 hours along the line Munich-Stuttgart-Trappes-Hemsby (Temps T-log p). Key: 1 - hectofeet.

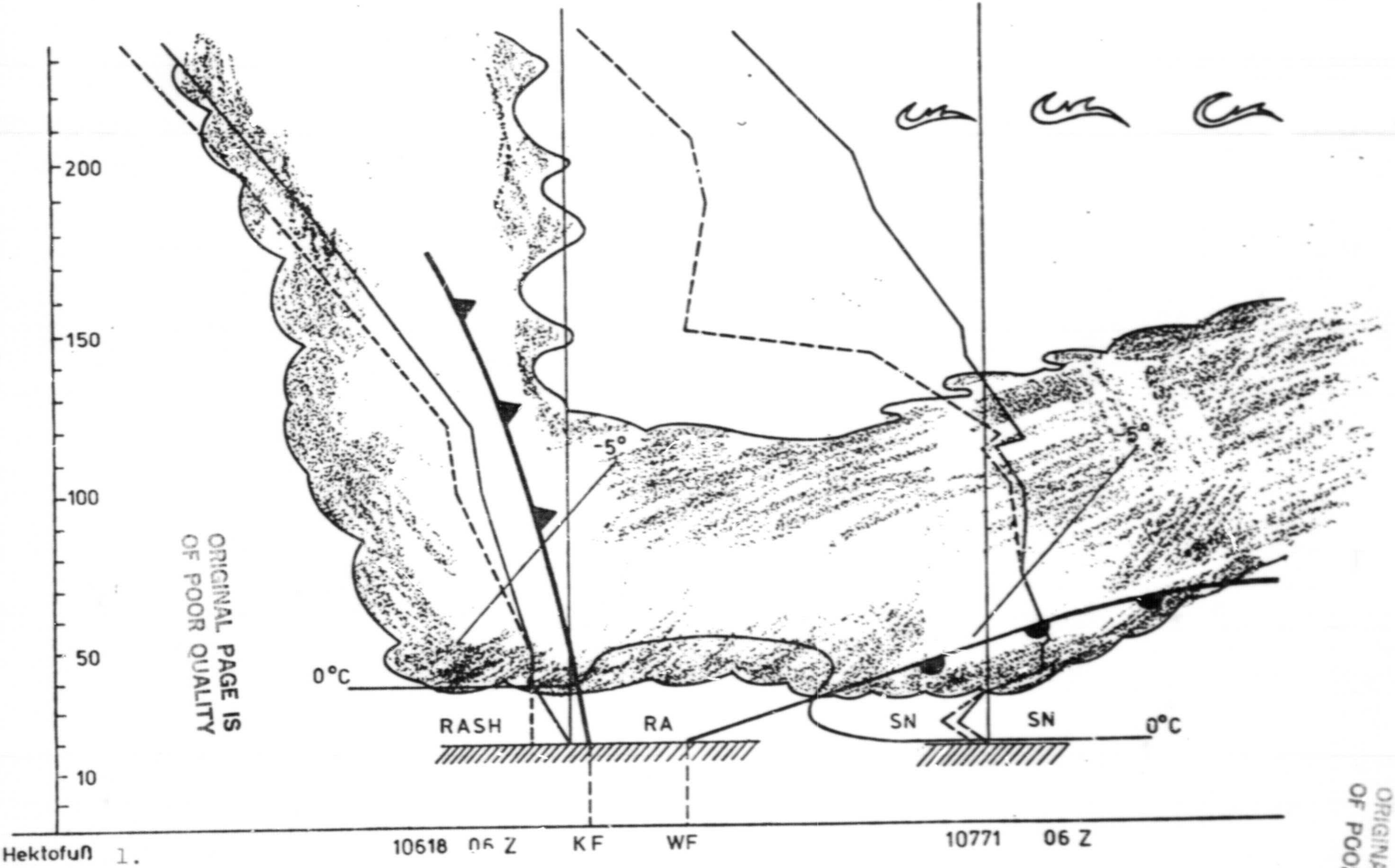

Figure 8. Cross-section through the front system of 23 March 1978 at 0600 hours along the line Gaermersdorf-Idar-Oberstein (Temps T-log p). Key: 1 - hectofeet.

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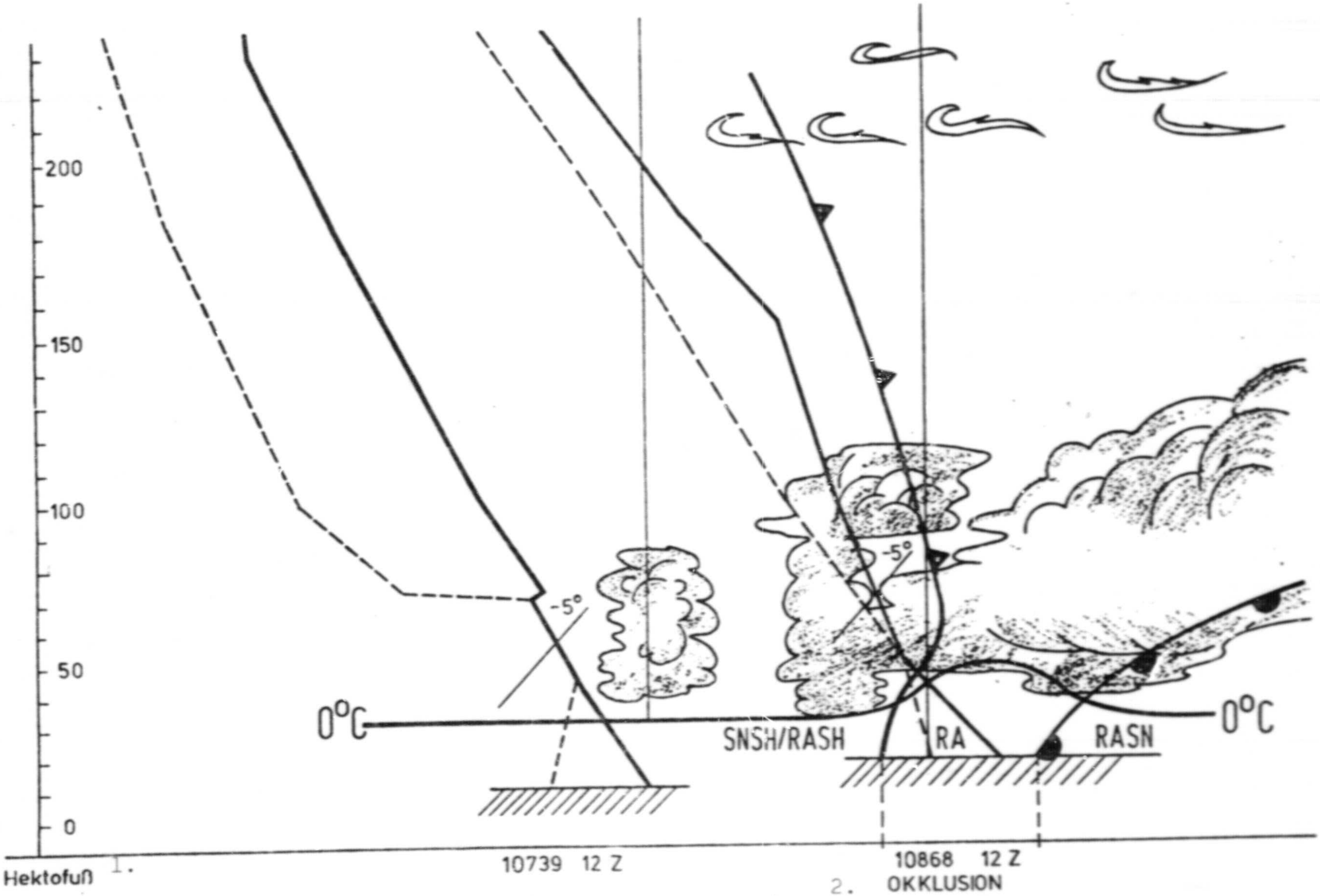

Figure 9. Cross-section through the front system of 23 March 1978 at 1200 hours along the line Munich-Stuttgart (Temps T-log p).
Key: 1 - hectofeet; 2 - occlusion.

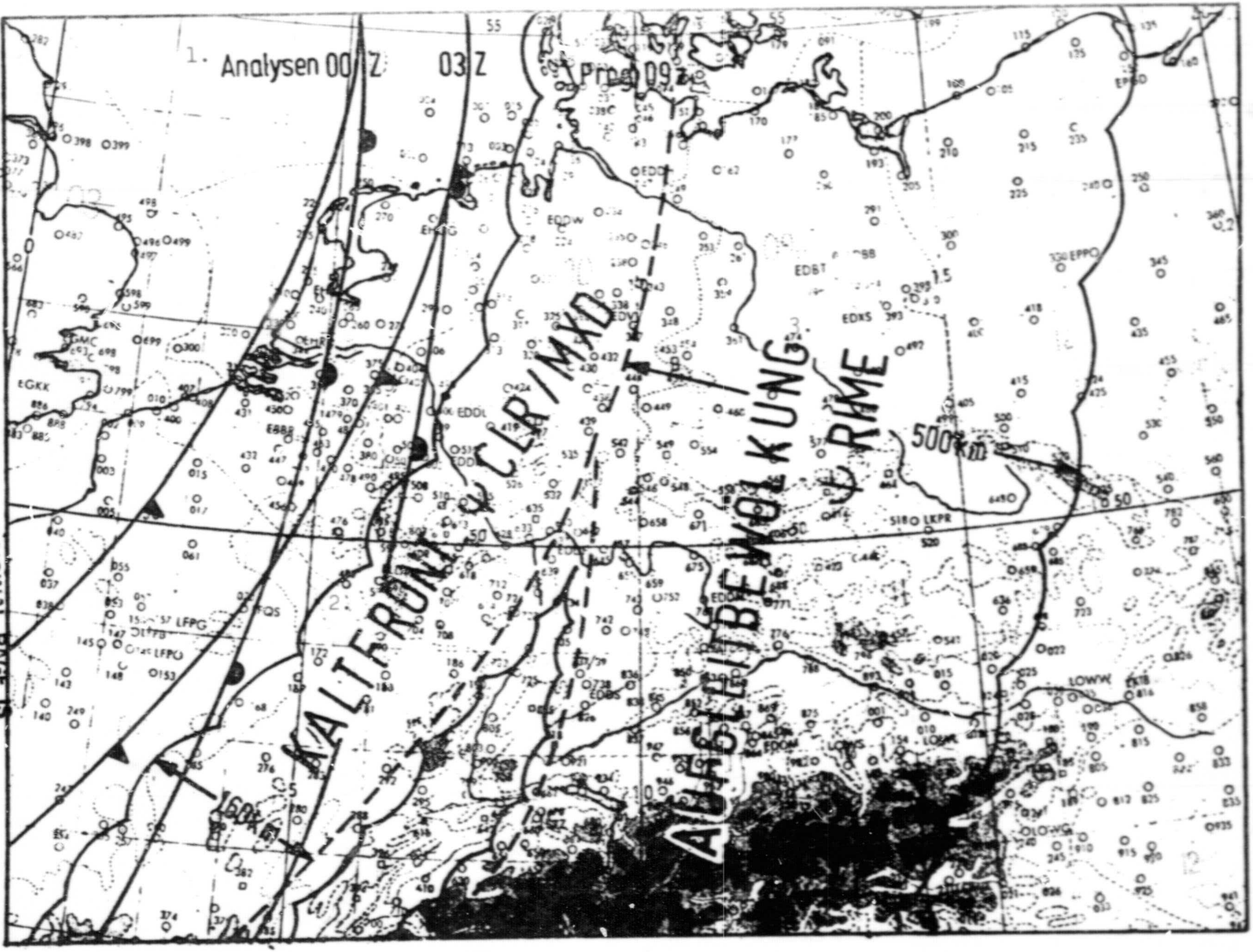

Figure 10. On 23 March 1978 between 0300 and 0600 hours for 0900 hours after [2] predicted icing regions.
Key: 1 - analyses, 2 - cold front, 3 - upslide clouds.

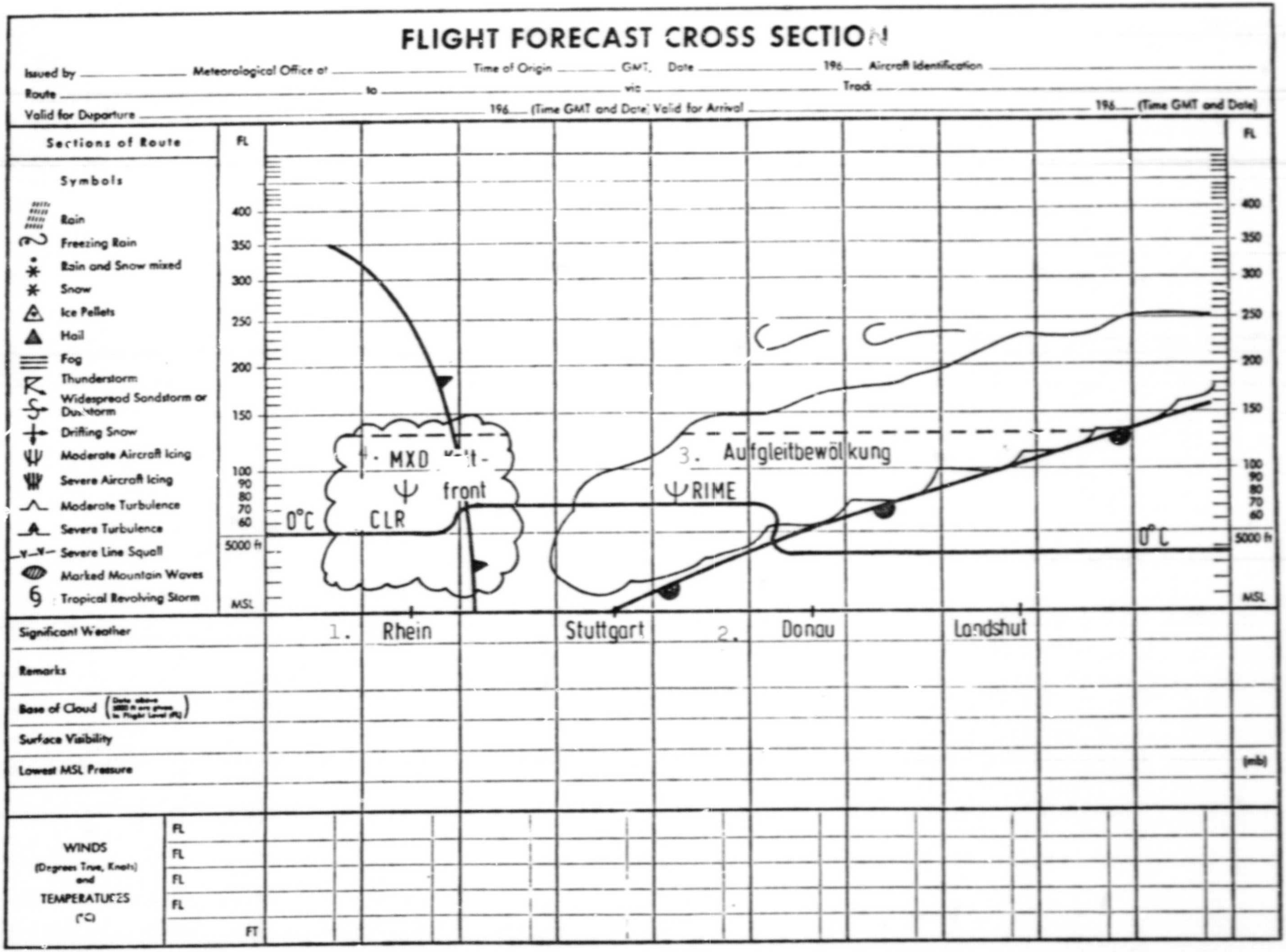

Figure 11. On 23 March 1978 between 0300 and 0600 hours for 0900 hours after [3] predicted icing zones.
Key: 1 - Rhine, 2 - Danube, 3 - upslide clouds, 4 - cold front.

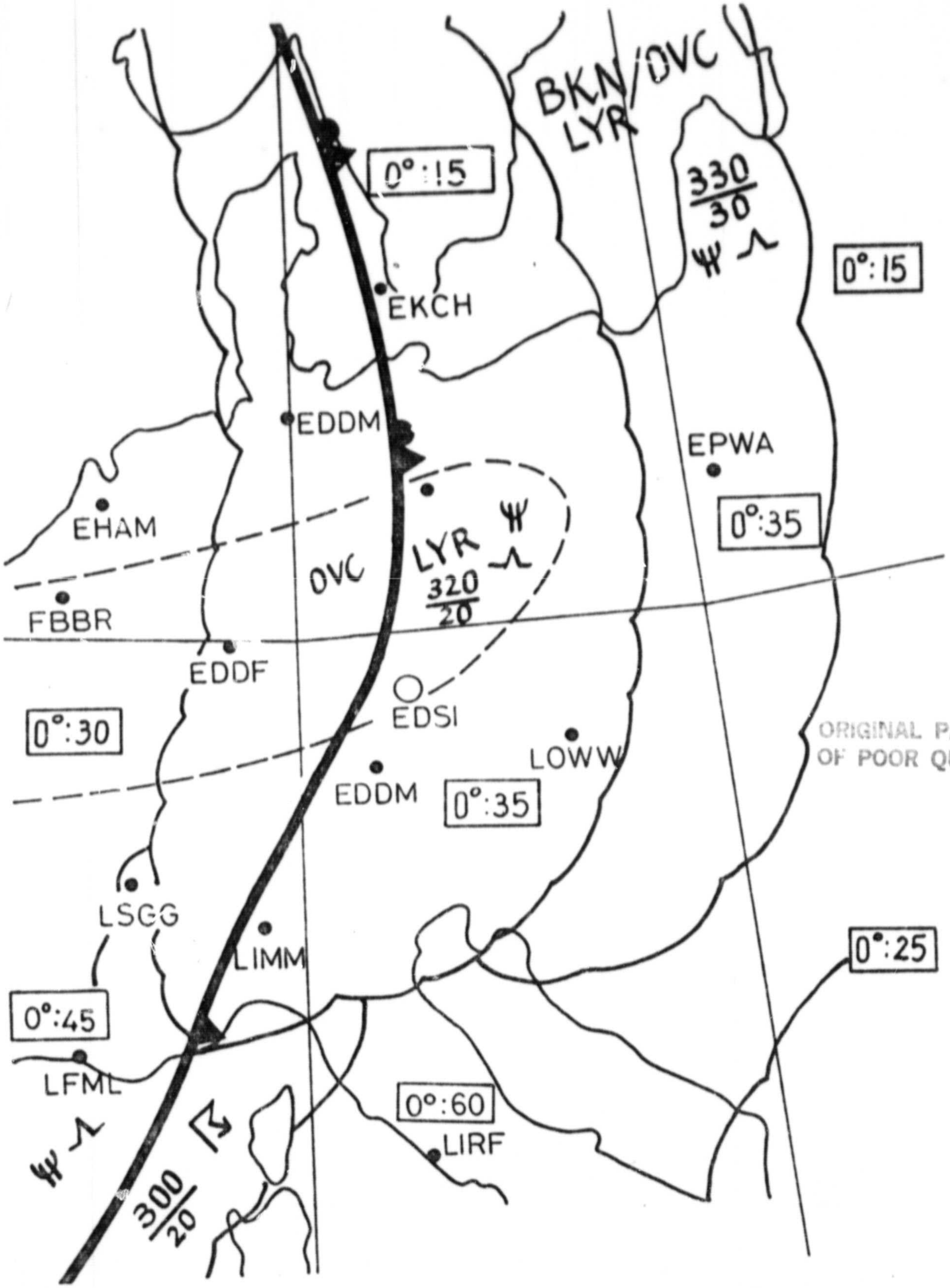

Figure 12. Section from the significant weather chart 850-150 mb of the German Weather Service of 23 March 1978, prediction for 1200 hours.

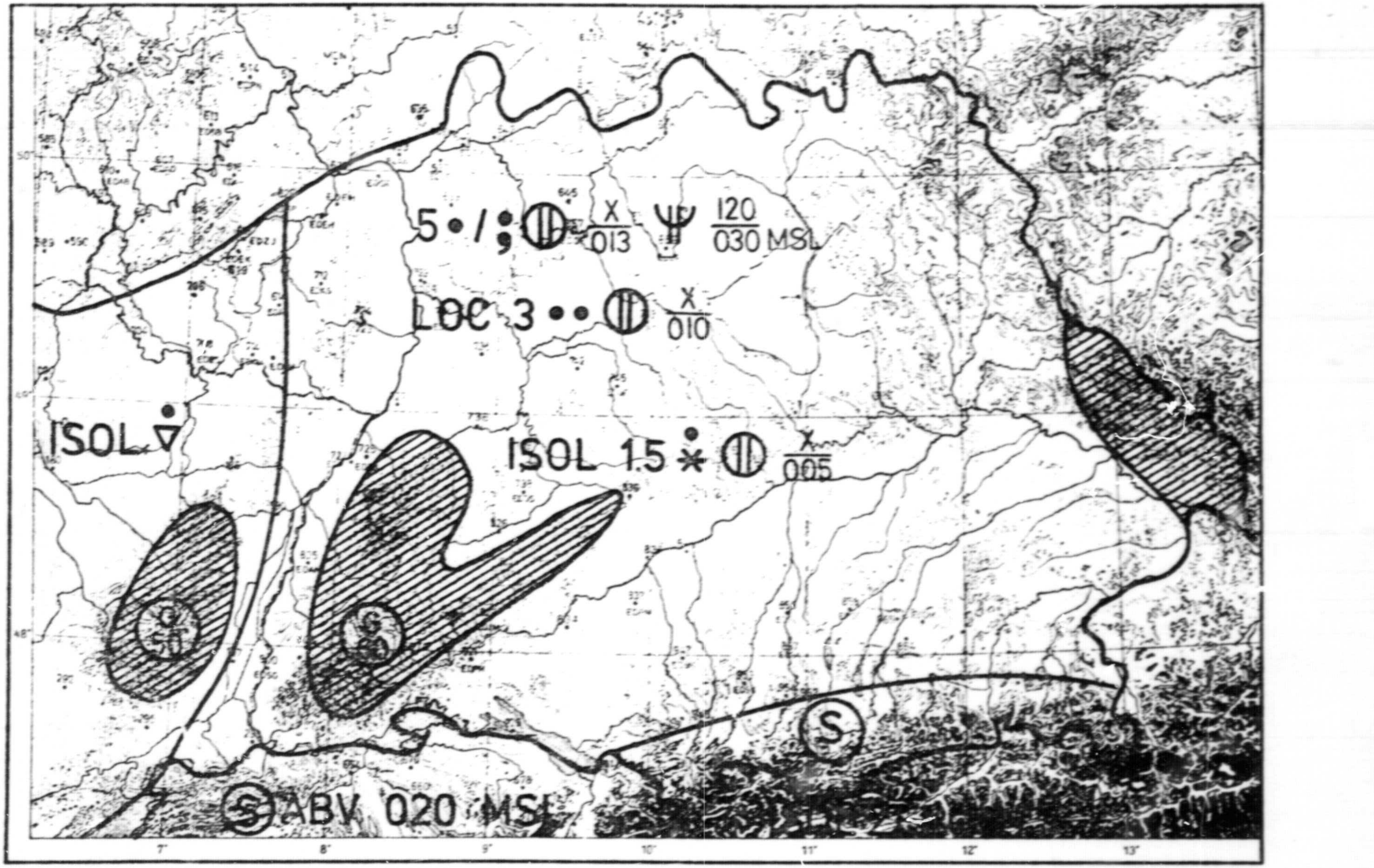

Figure 13. Section from the tactical region chart No. 9 of the South Management Center of the Army Geophysical Advisory Center of 23 March 1978, prediction for 0900 hours.

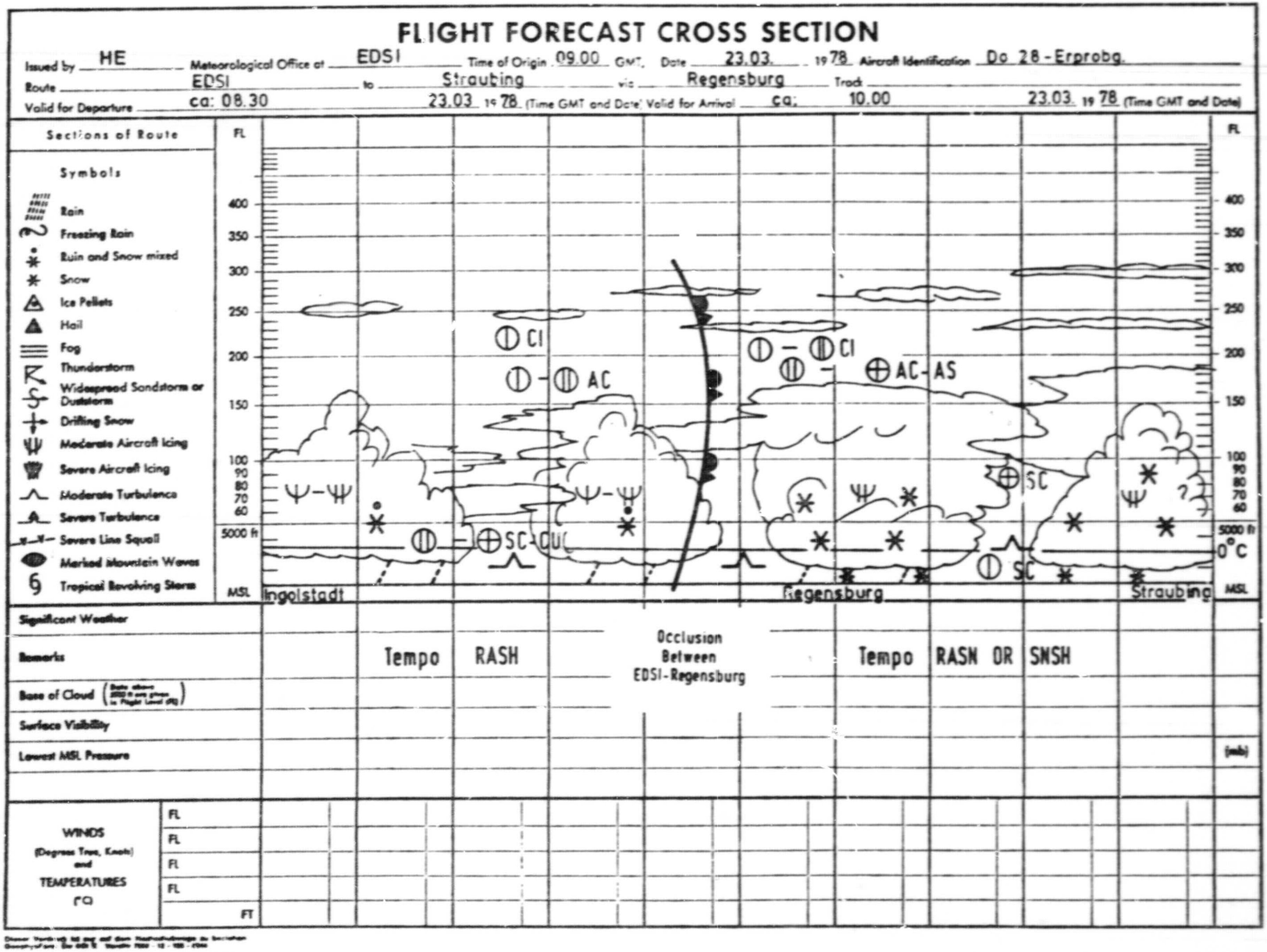

Figure 14. Flight forecast cross-section of 23 March 1978 for the route Ingolstadt-Straubing, valid between 0830 and 1000 hours.

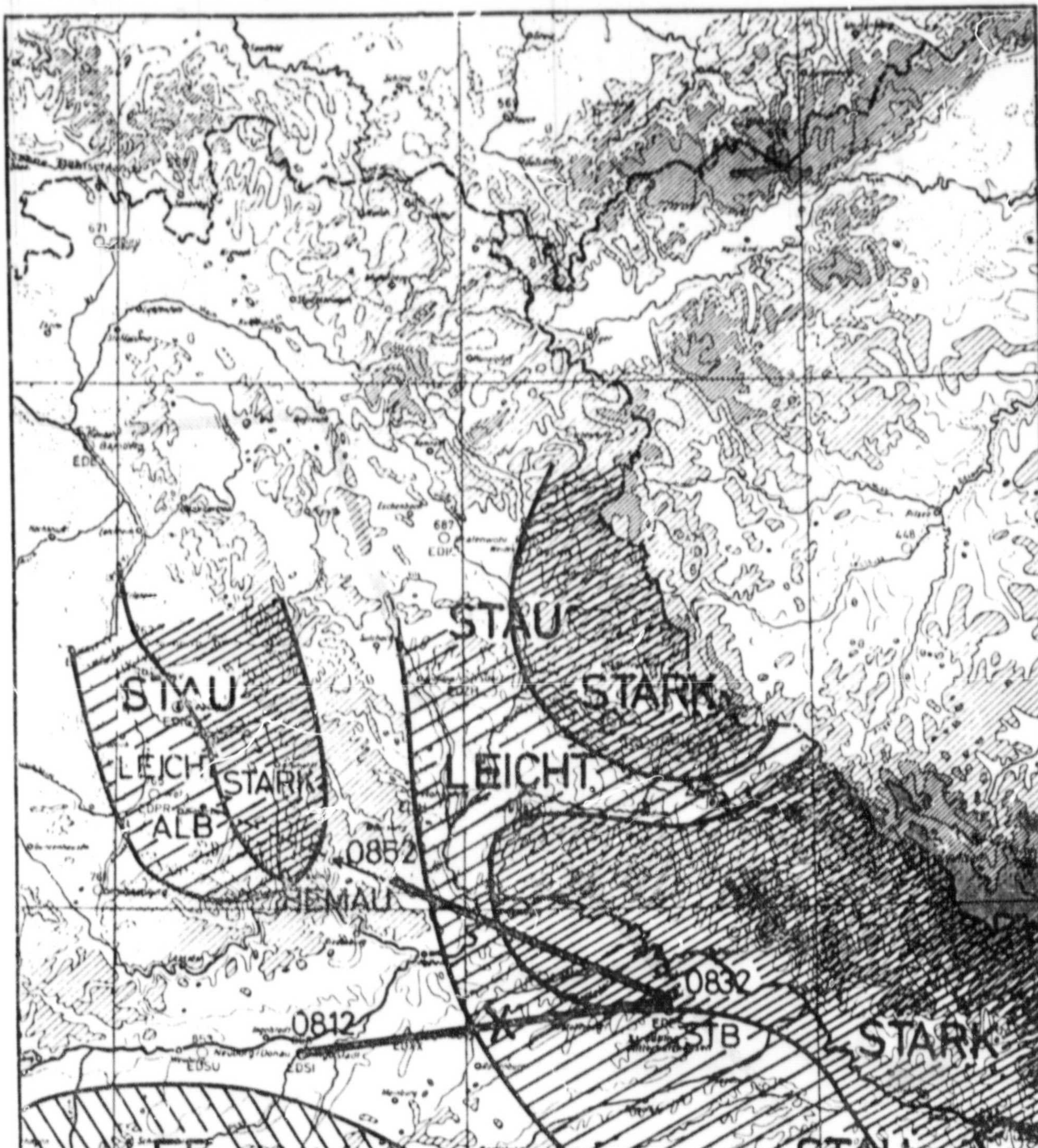

Figure 15. Flight route of the Do 28 from Manching (EDSI) to Hemau via Straubing (STB). The illustrated stagnation and lee regions were taken from the chart AWGeophys 1973, file No. SK-20-K-LL-SW.

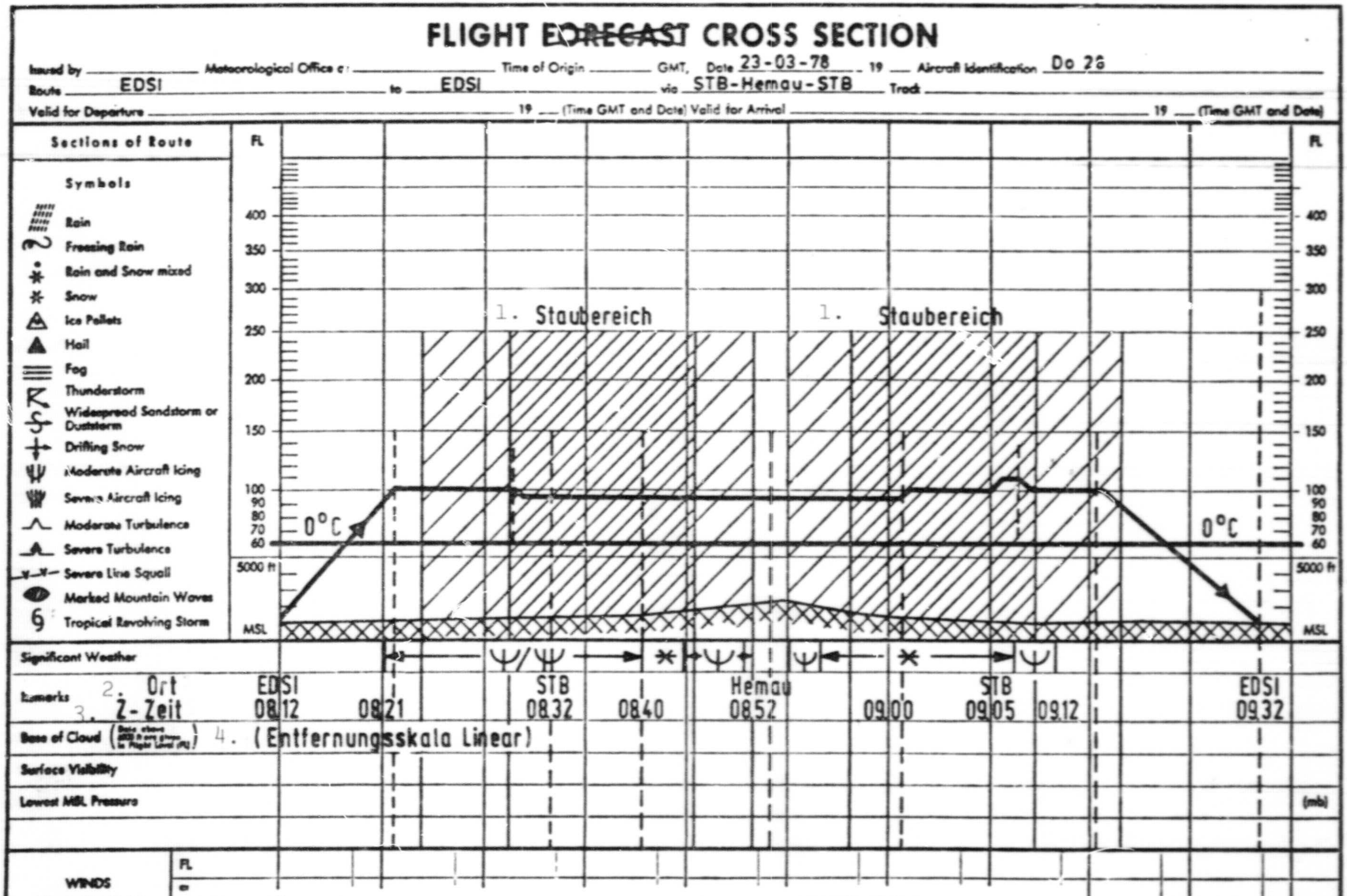

Figure 16. Flight cross-section for the flight of the Do 28, using the record of the on-board engineer. The limits of the stagnation regions were taken from figure 15. Key: 1 - stagnation region; 2 - place; 3 - time; 4 - linear distance scale.

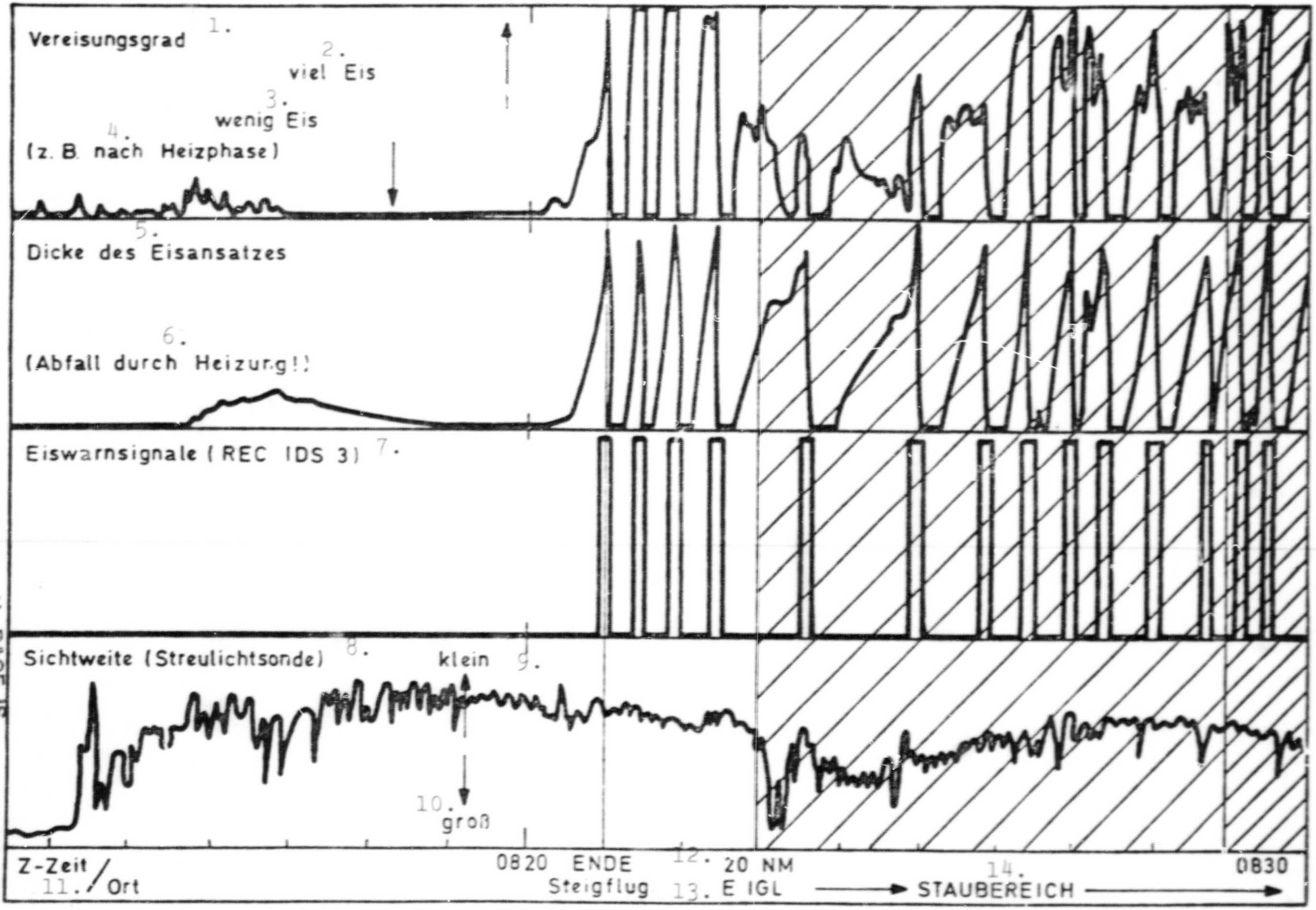

Figure 17. Measurement record of the flight phase: ascent and entry into the stagnation zone in front of Straubing (STB). Key: 1 - icing degree; 2 - much ice; 3 - little ice; 4 - e.g. after heating phase; 5 - thickness of ice charge; 6 - fall-off due to heating; 7 - ice warning signal; 8 - visibility (scattered light probe); 9 - small; 10 - large; 11 - time/place; 12 - end; 13 - ascent; 14 - stagnation region.

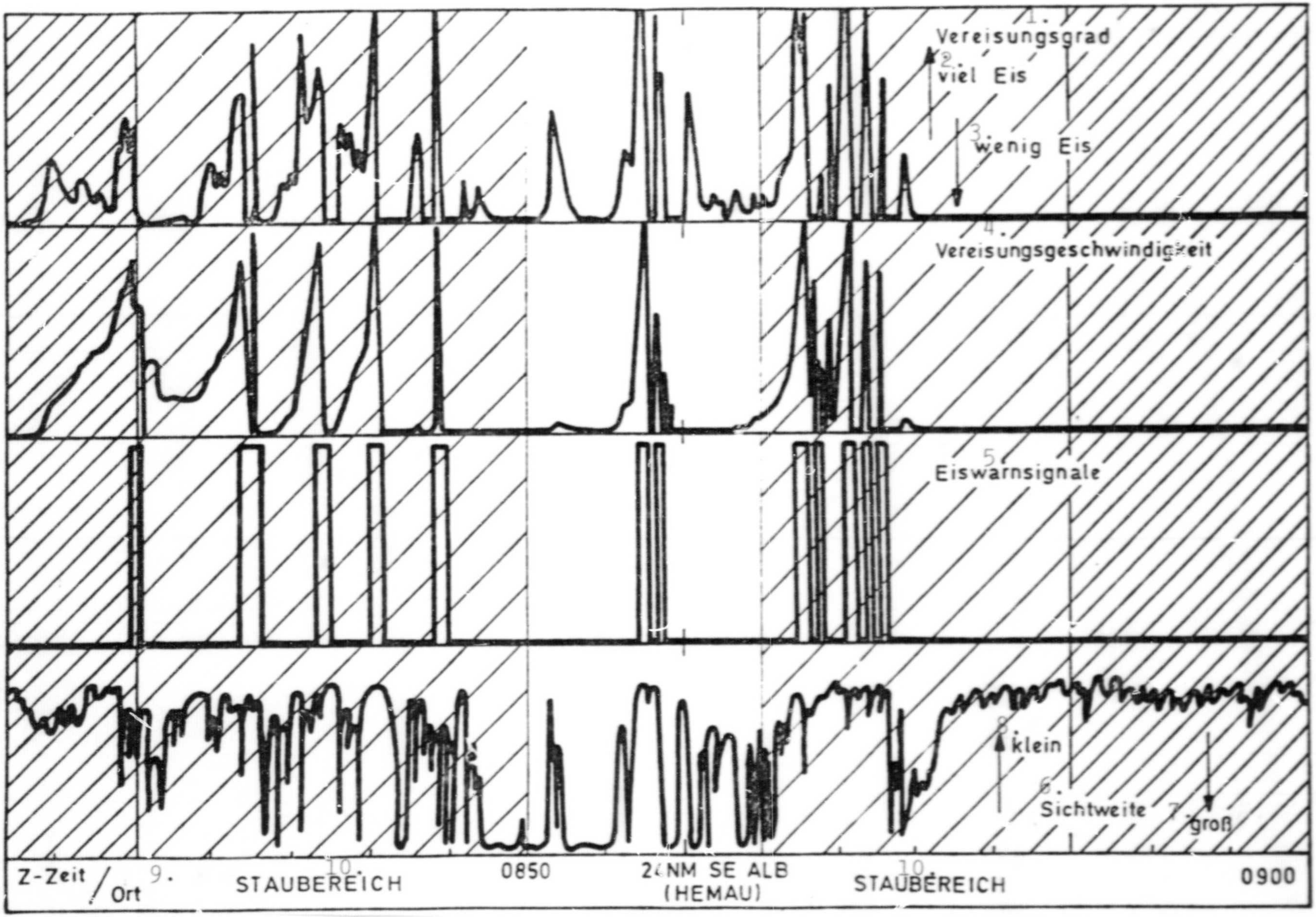

Figure 18. Measurement record of the flight phase: flight from the stagnation region to Straubing via Hemau (course change by 180 degrees) until renewed entry into the stagnation region in front of Straubing. Key: 1 - icing degree; 2 - much ice; 3 - little ice; 4 - icing rate; 5 - ice warning signals; 6 - visibility; 7 - large; 8 - small; 9 - time; 9 - time/place; 10 - stagnation region.

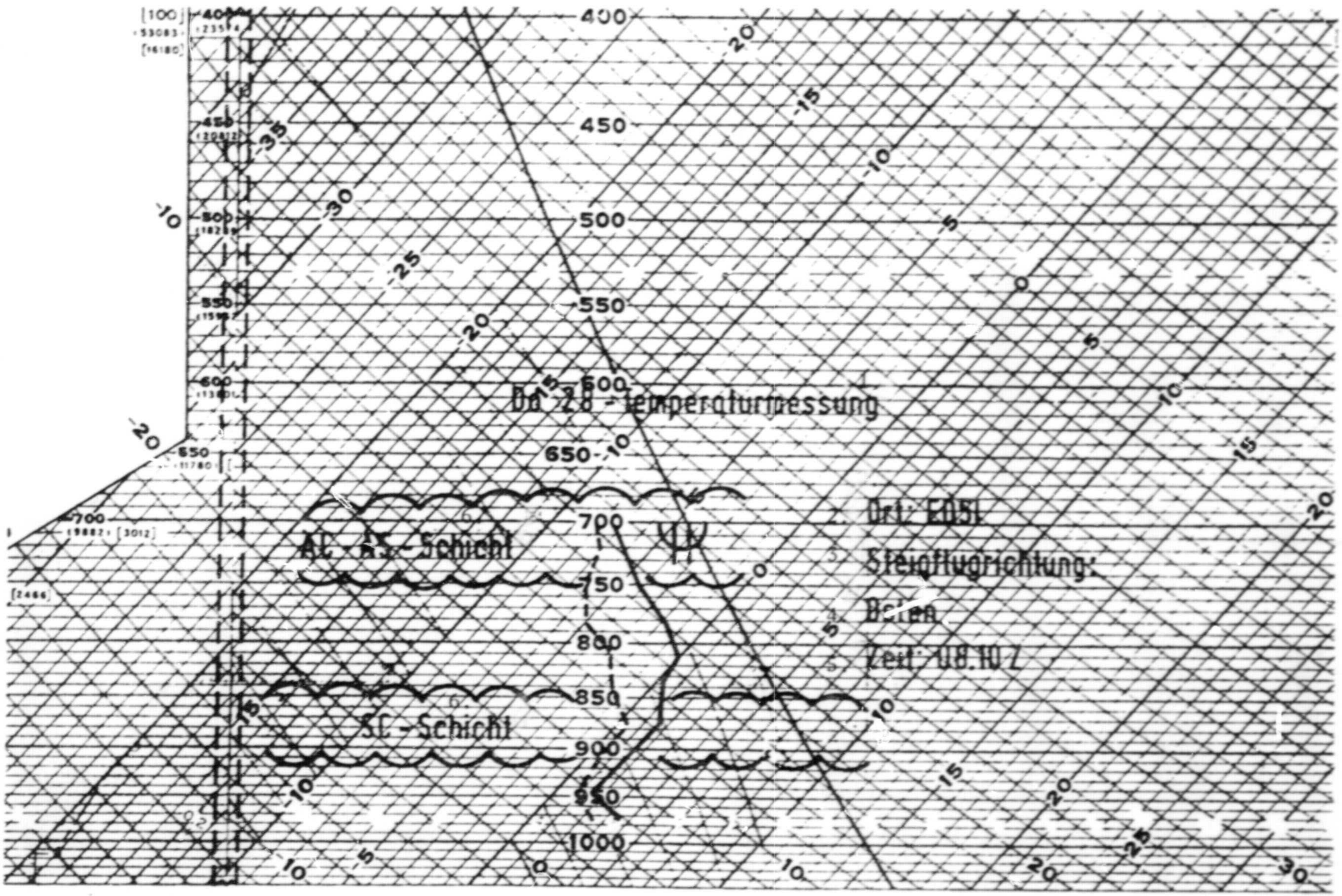

Figure 19. Temperature profile on ascent of the Do 28.
Key: 1 - temperature measurement; 2 - place; 3 - ascent direction; 4 - time; 5 - layer.

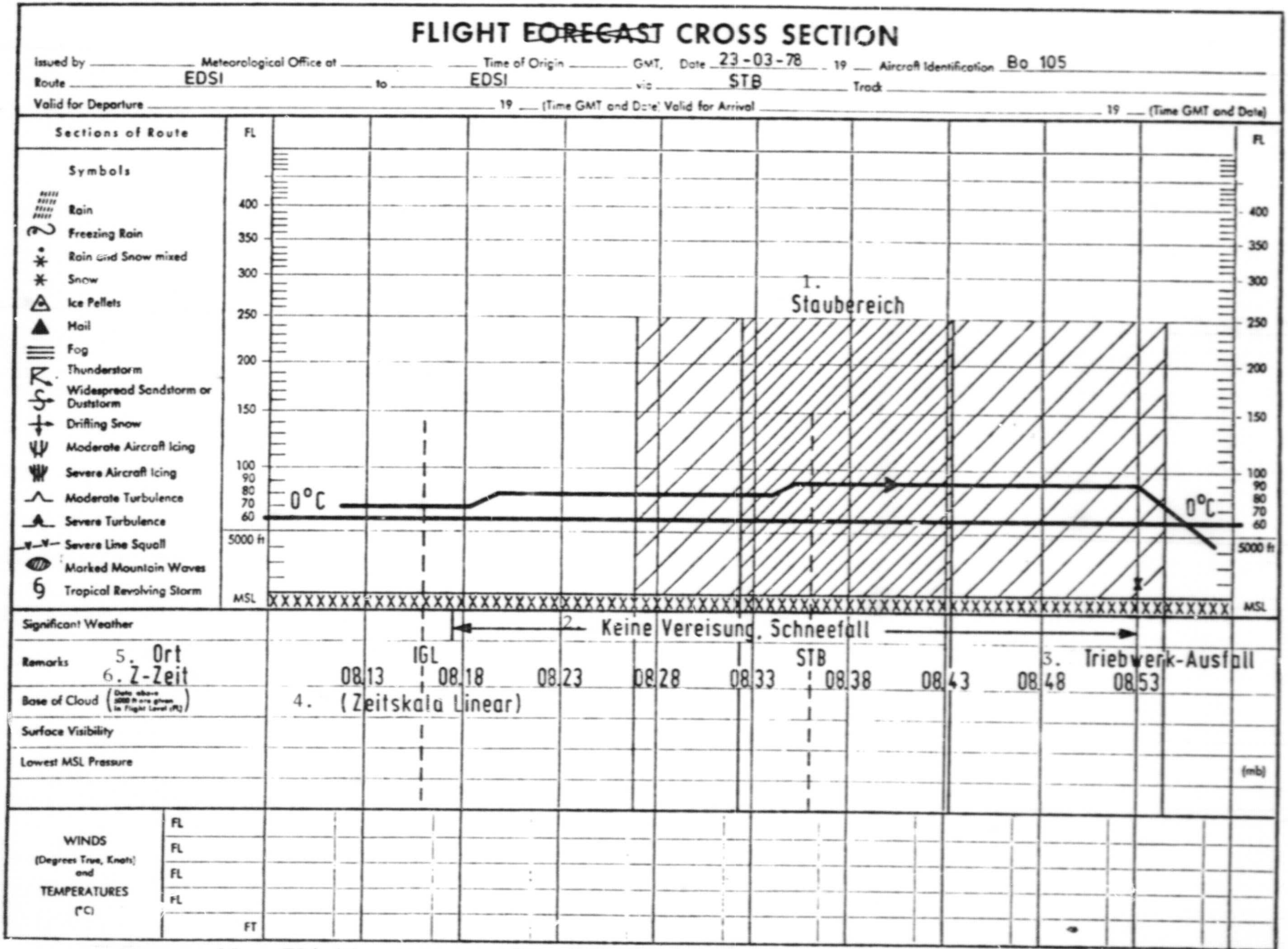

Figure 20. Flight cross-section for the Bo 105 helicopter, shown from the pilot's record. The limits of the stagnation region were taken from figure 15. Key: 1 - stagnation region; 2 - no icing, snowfall; 3 - engine failure; 4 - linear time scale; 5 - place; 6 - time.

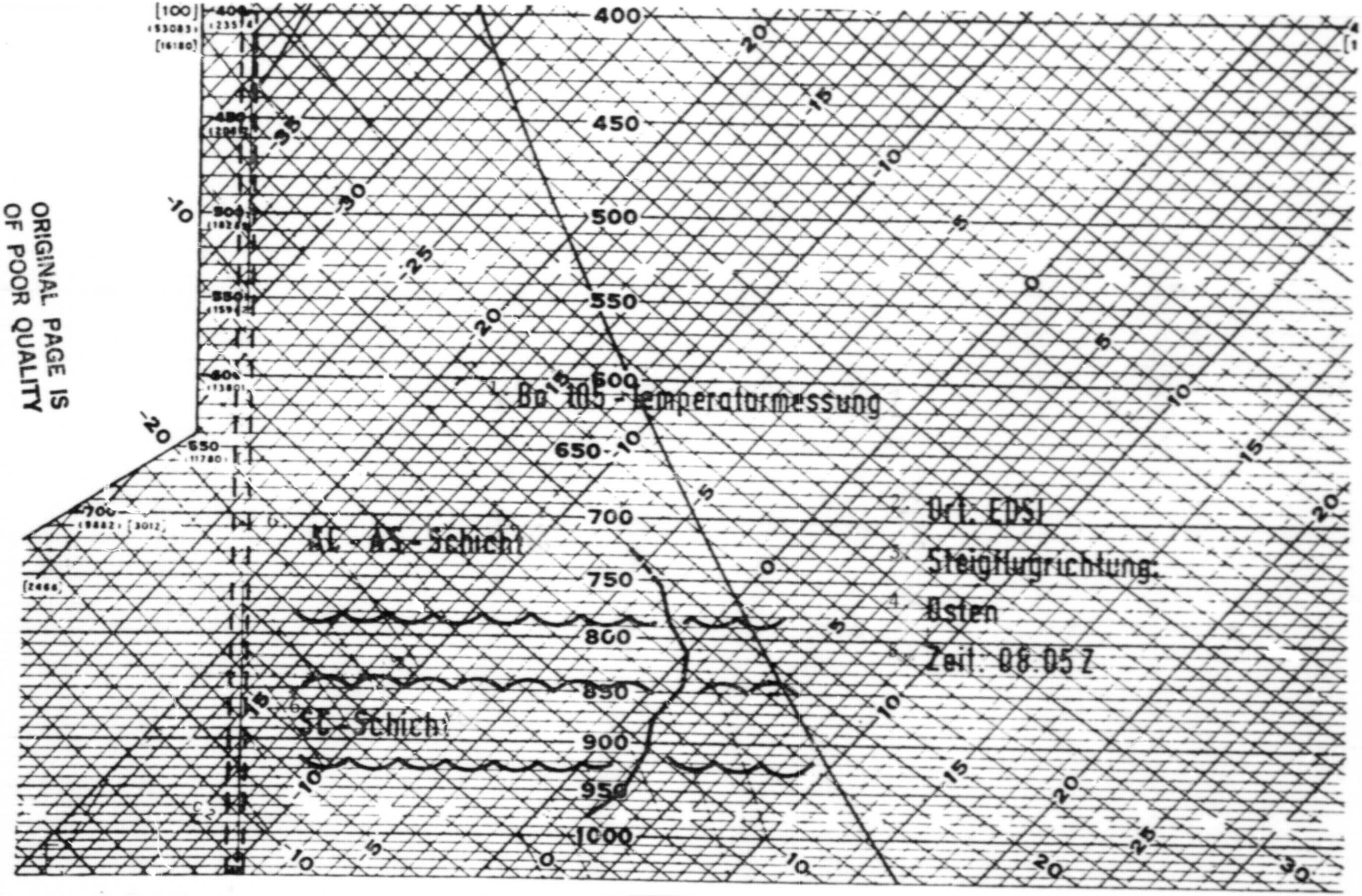

Figure 21. Temperature profile measured on the ascent of the Bo 105 helicopter. Key: 1 - temperature measurement; 2 - place; 3 - ascent direction; 4 - east; 5 - time; 6 - layer.

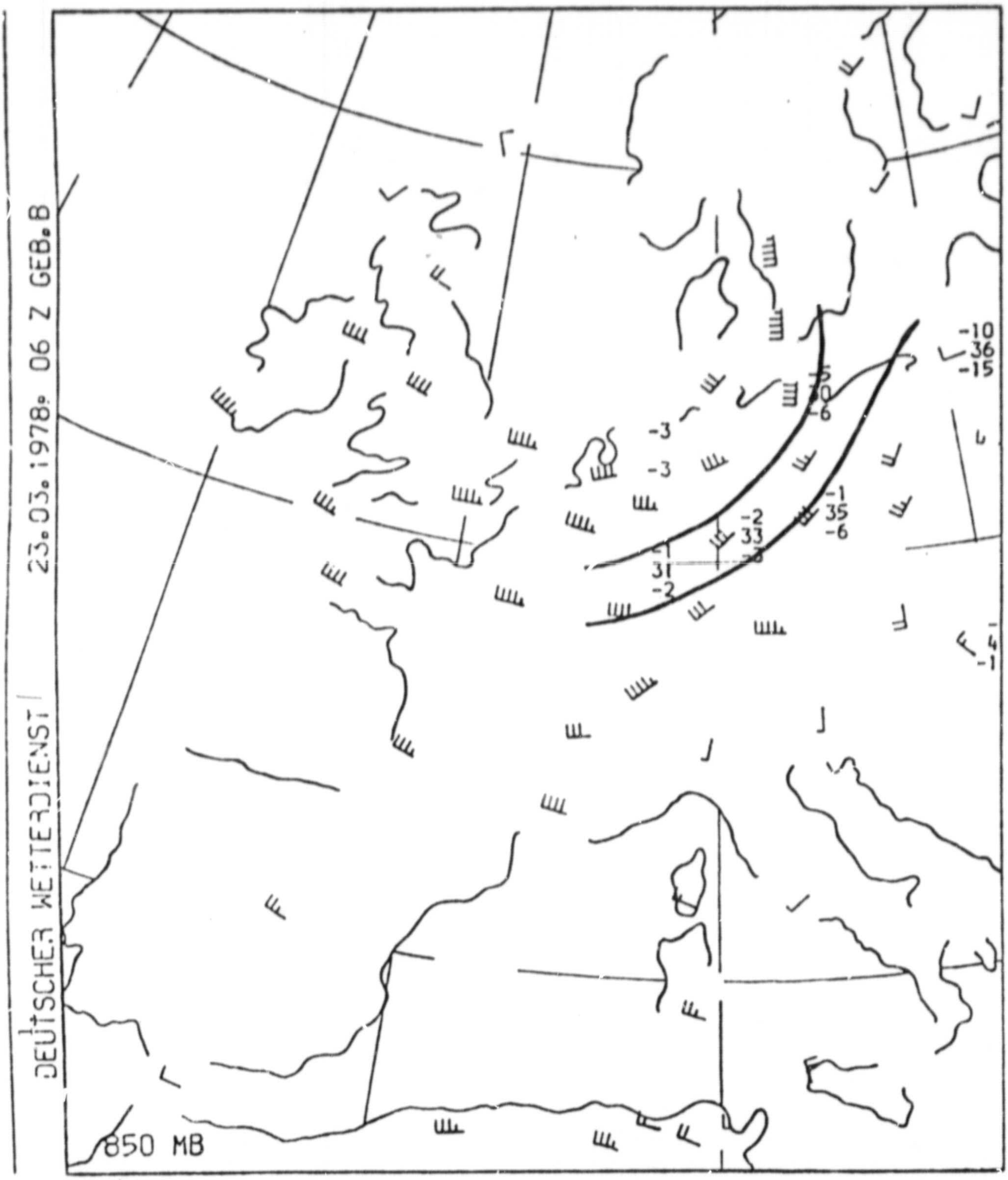

Figure 22. High-altitude winds at 850 mbar on 23 March 1978 at 0600 hours with flow lines.
Key: 1 - German weather service.

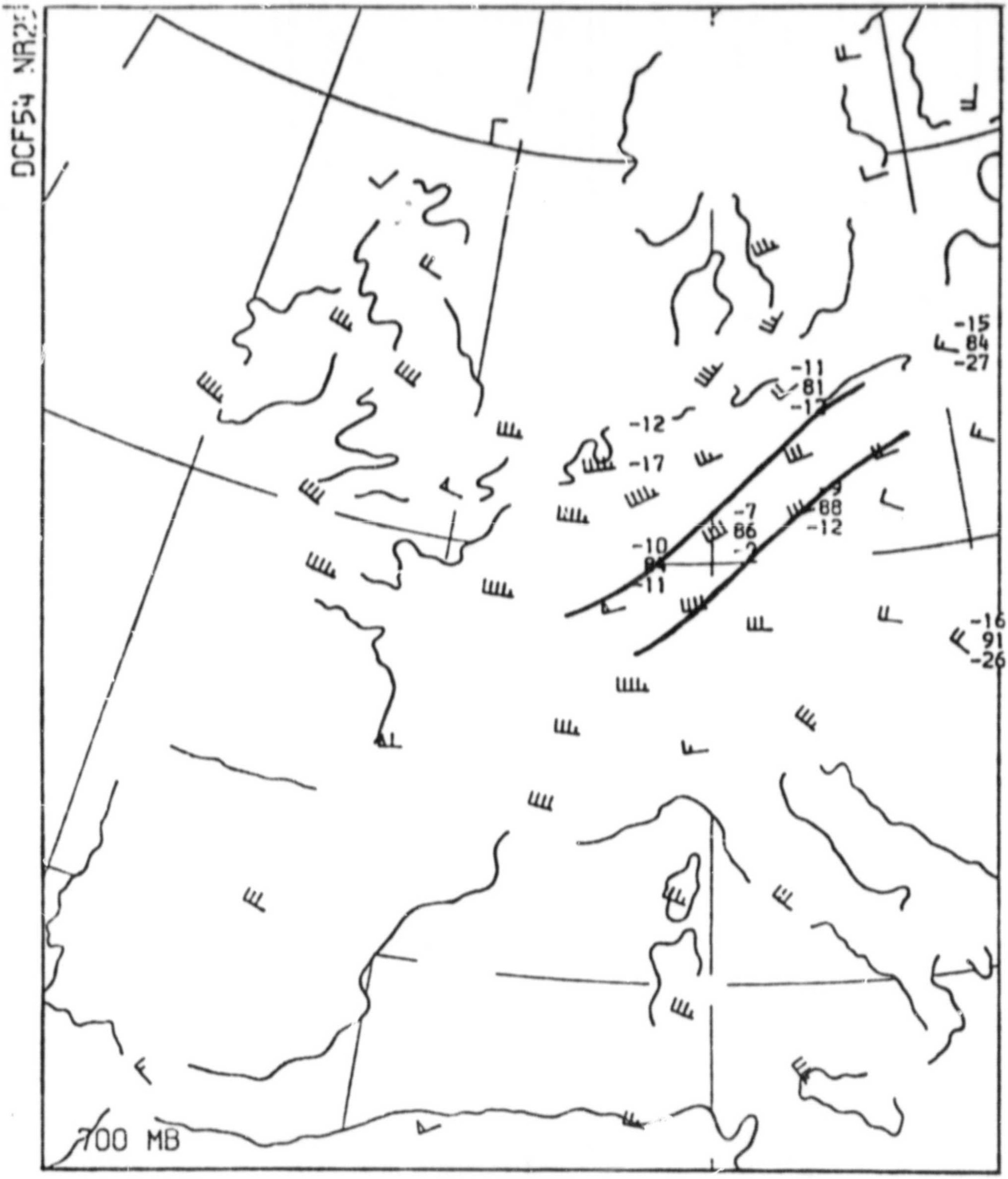

Figure 23. High-altitude winds at 700 mb on 23 March 1978 at 0600 hours with flow lines.

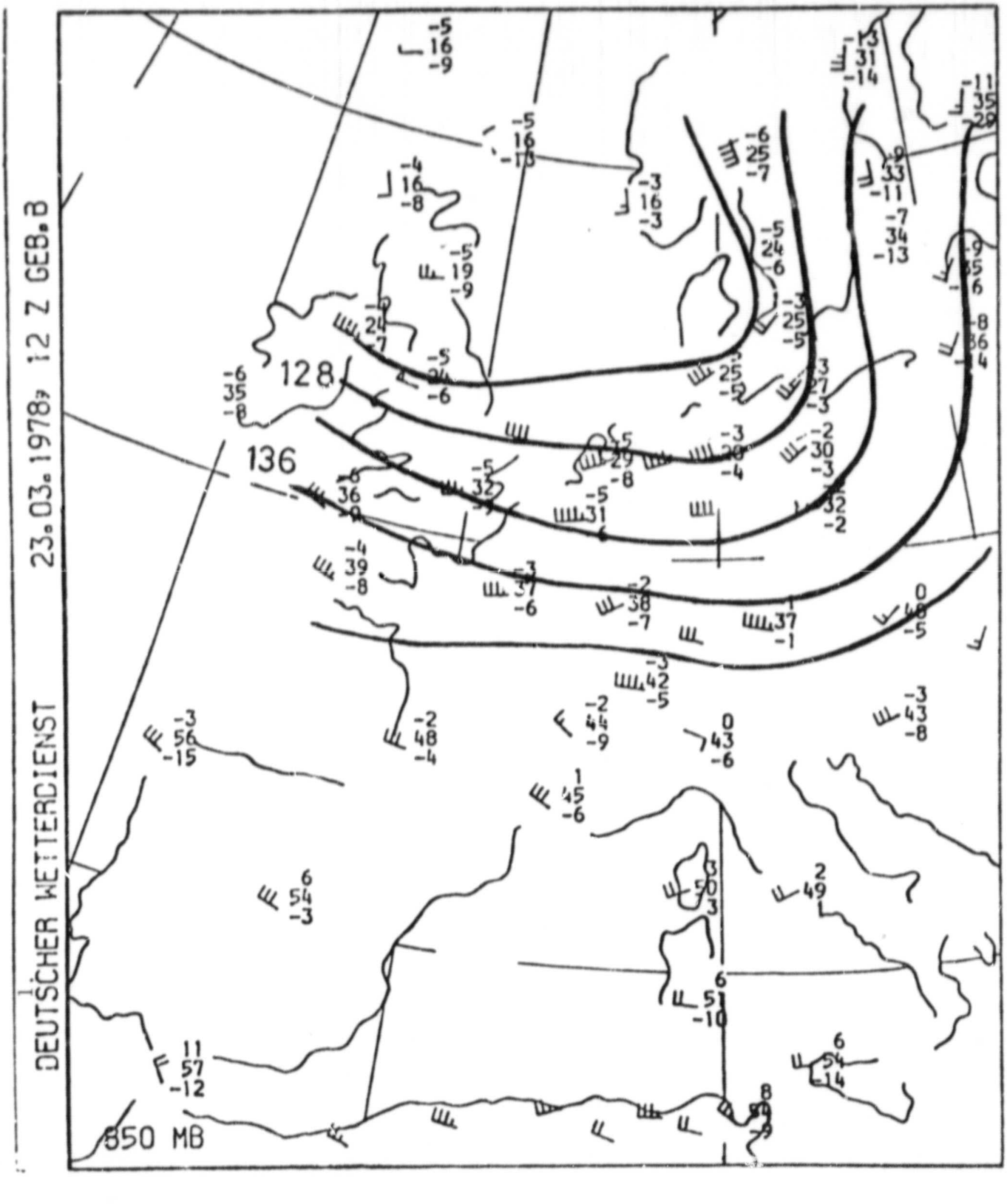

Figure 24. Absolute topography 850 mbar on 23 March 1978 at 1200 hours. Spacing of isohypses 4 geopotential decameters.
Key: 1 - German weather service.

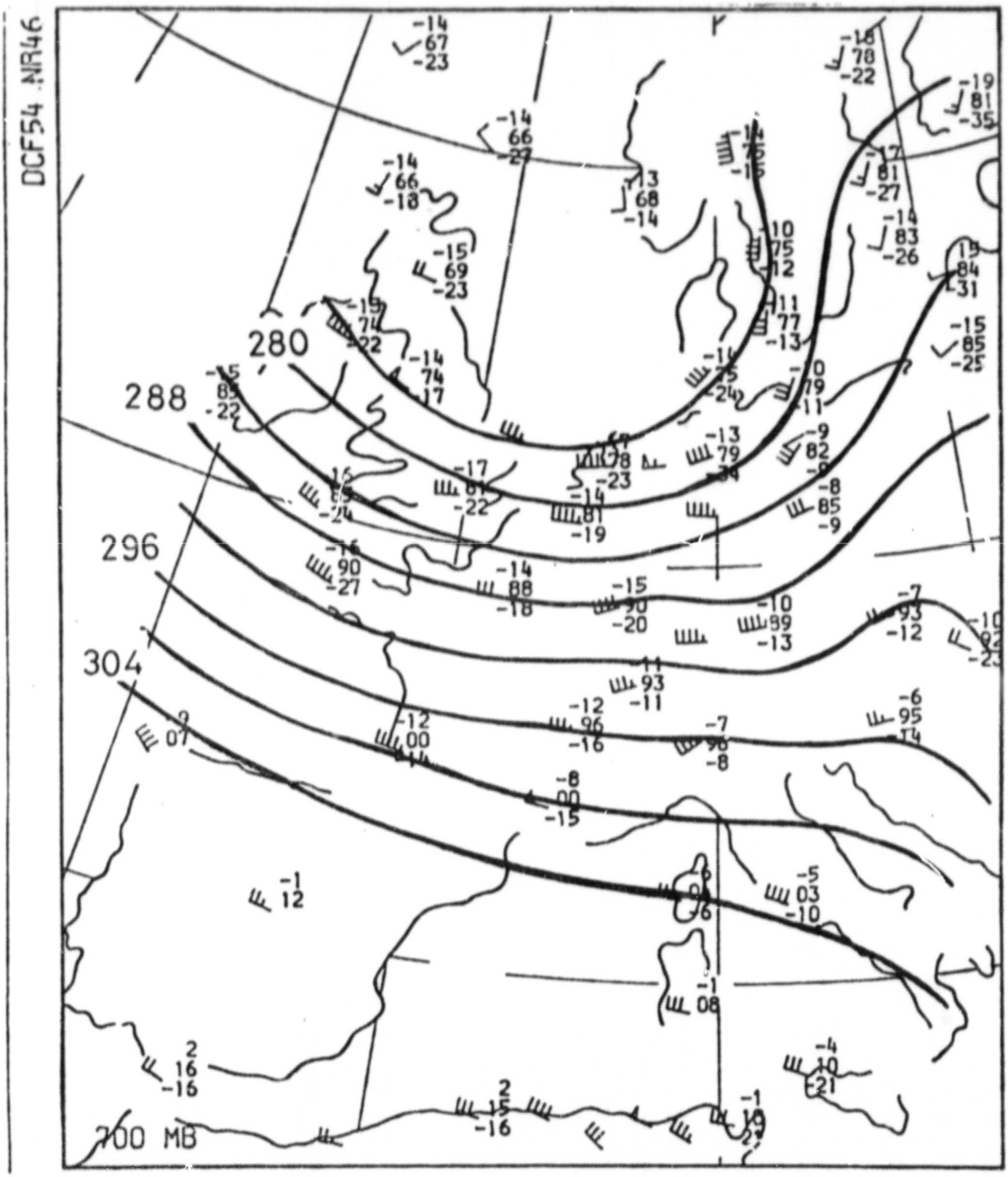

Figure 25. Absolute topography 700 mbar of 23 March 1978 at 1200 hours. Spacing of the isohypses 4 geopotential decameters.

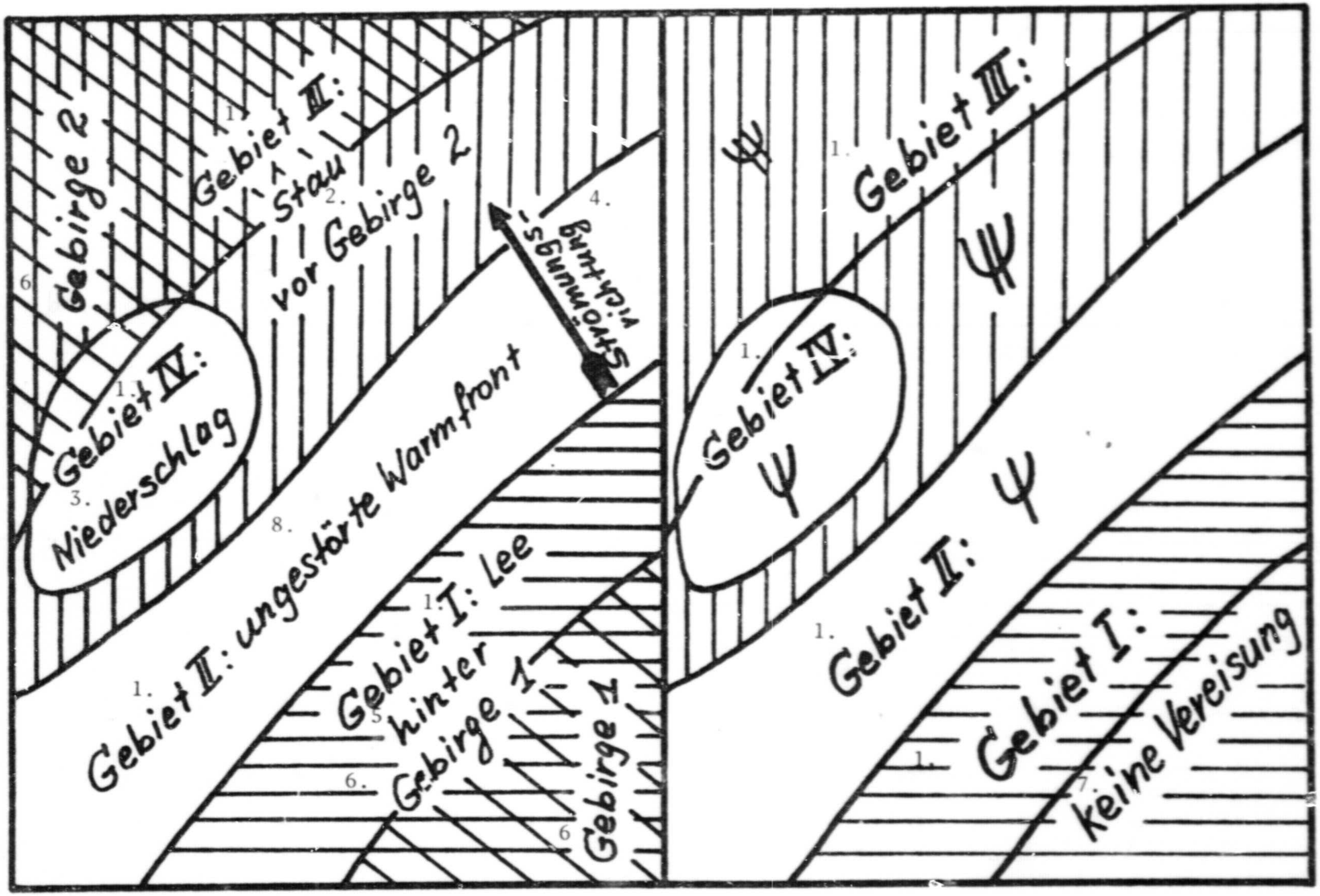

Figure 26. Presentation of the obtained icing theory. Key: 1 - region; 2 - stagnation in front of region 2; 3 - precipitation; 4 - flow direction; 5 - behind mountain 1; 6 - mountain; 7 - no icing; 8 - undisturbed warm front.

Station: EDPS		Ortskennung: 1 10 - 788

2 **Wettertagesbogen II**

METAR/SPECI

3. Datum	Blatt Nr
23.03.1978	4.

GGgg	dddff	$V f_m f_m$	VVVV	$RV_RV_RV_RV_R$	$/D_RD_R$	w'w'	$N_sCCh_sh_sh_s$	$N_sCCh_sh_sh_s$	$N_sCCh_sh_sh_s$	$N_sCCh_sh_sh_s$	(M)T'T'	(M)$T'_dT'_d$	$P_HP_HP_HP_H$	5. Zusätze	6. Farb-Stufe	7. Farbstufen-vorhersage	8. Abg.-Zeit / Zeichen
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0552	13009		5000			71 SN	6Sc036	8As080			M01	M03	1007				
0652	12011		3000			71 SN	3Sc018	8Sc036			M01	M03	1006				
0752	13009		2000			71 SN	3Sc018	8Sc030			M01	M02	1006				
0852	12011		1700			73 SN	2Sc018	8Sc030			M00	M02	1005				
0905	12012		0800			75 XXSN	9//003										
0916	11011		1800			68 RASN	8Sc027										
0952	10012		3000			60 RA	3Sc015	8Sc030			M00	M01	1004				
1052	11008		4000			61 RA	6Sc035	8As090			00	M01	1004				
1152	10006		5000			61 RA	3Cu018	6Sc033	8As090		01	M00	1005				
1252	10004		6000			21 RERA	3Cu018	5Sc035	7Ac090		03	01	1006				

9 · Geprüft: ....

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Appendix 1. METAR data for the Straubing airfield (EDPS) on 23 March 1978 between 9552 and 1252 hours.

Key: 1 - location id.; 2 - daily weather chart II; 3 - date; 4 - page no.; 5 - supplement; 6 - color stage; 7 - color stage prediction; 8 - time