KfK 4167
Februar 1987

Measuring Activities of the TULLA-Experiment

(Field Phase Report)

S. Vogt, F. Fiedler
Institut für Meteorologie und Klimaforschung

Kernforschungszentrum Karlsruhe

KERNFORSCHUNGSZENTRUM KARLSRUHE

Institut für Meteorologie und Klimaforschung

KfK 4167

Measuring Activities of the TULLA-Experiment
(Field Phase Report)

S. Vogt
F. Fiedler

Kernforschungszentrum Karlsruhe GmbH, Karlsruhe

Kernforschungszentrum Karlsruhe GmbH
Postfach 3640, 7500 Karlsruhe 1

ISSN 0303-4003

Summary

In order to improve our knowledge about the transport and chemical conversion of airborne pollutants in areas of several hundred kilometres sidelength, a field experiment was carried out in the Federal State of Baden-Württemberg in March 1985. The name of the experiment was TULLA ("Transport and Transformation of Air Pollutants in the State of Baden-Württemberg and from neighbouring countries").

The objective of the experiment required a simultaneous registration of the timely and spatial distribution of the emissions, the relevant meteorological parameters for the transport, the chemical reaction rates as well as the timely and spatial distribution of the immissions in a three-dimensional framework.

All measuring activities during TULLA are described in the following report. No results are given, but the course of the experiment and the measurements that were carried out, are reported.

Zusammenstellung der Meßaktivitäten während des TULLA-Experiments

Zusammenfassung

Zur Verbesserung der Kenntnisse über den Transport und die chemische Umwandlung von Schadstoffen in Gebieten der Größe mit einigen hundert Kilometern Seitenlänge wurde im März 1985 im Gebiet von Baden-Württemberg ein Feldexperiment durchgeführt. Das Experiment trägt den Namen TULLA ("Transport und Umwandlung von Luftschadstoffen im Lande Baden-Württemberg und aus Anrainerstaaten").

Die Zielsetzung des Experiments erforderte eine gleichzeitige Erfassung der zeitlichen und räumlichen Verteilung der Emission, der für den Transport relevanten meteorologischen Parameter, der luftchemischen Reaktionsraten sowie der zeitlichen und räumlichen Verteilung der Immissionen in einem dreidimensionalen Raster.

Im vorliegenden Bericht werden alle Meßaktivitäten während TULLA beschrieben. Es werden keine Ergebnisse gebracht, sondern über den Verlauf des Experiments und die dabei durchgeführten Messungen wird berichtet.

Table of Contents | Page

Table of Contents cont'd. Page

1. Introduction

In order to reduce emissions effectively and economically, a better insight into the cause - effect relation is required.

Knowledge of the transport and the chemical conversion of airborne pollutants in areas of several 100 km sidelength is still rather incomplete. Government regulations have provided that the ground concentration near the emission sources do not exceed the given maximum values. However, it can only be vaguely imagined where and in which concentrations the material is transported, resp. under which chemical conversions it is transported.

To improve the current knowledge, a detailed experiment was planned and then carried out in spring 1985 in the area of Baden-Württemberg. The Experiment carries the name of TULLA ("Transport and Transformation of Air Pollutants in the State of Baden-Württemberg and from neighbouring countries").

Increasing awareness of the influence of human activities on the environment, i.e. both on the inanimate and the living nature, has increased the need for extensive studies of air pollutants in mesoscale regions of the atmosphere. Although the knowledge about the processes involved is still inadequate, it is often air pollutants that can be traced back as the causes of forest damages and of damages to buildings. Sulfurdioxide, nitrooxides and other substances, especially those interacting with ozone and hydrocarbonates, are of special importance.

2. Aims of the Experiment

In a region that is approximately of the size of Baden-Württemberg, measurements and numerical model-simulations of the transportation of airborne pollutants are to be made and a mass balance is to be estimated. In addition, numerical models are to be used to simulate the distribution of pollutants. For two reasons, SO_2 is used as a leading tracer:

a) SO_2 quite often occurs in concentrations which can be recorded from the ground as well as from an aircraft without any major technical measuring problems.

b) The average residence time of SO_2 in the atmosphere is long enough, so that for a mass-balance within the area of Baden-Württemberg the chemical conversion reactions can be neglected for a first approximation.

The measurements and numerical model-simulations aim at the following problems:

a) Can, according to present emission source configurations and given topographical influences of the atmospheric flow field, so called dispersion-lanes orginate and be located?

b) How does advection of SO_2 from adjoining areas and sources within the area contribute to the mass balance?

c) How does the reduction of the source strength influence the emission-field in Baden-Württemberg?

d) How do concentration fields and deposition of SO_2 react on different meteorological conditions?

3. Planning and Preparation

3.1 Concept of the TULLA Experiment

In order to achieve the objectives of the experiment, simultaneous measurements of the time and space distribution of the sources, the relevant meteorological parameters, the time and space distribution of the emissions and also of the most important reaction partners of SO_2 within a three-dimensional screen was necessary. Therefore, the measurements concentrated on a complete determination of all terms of the mass balance during some typical episodes. For these activities, three weather types have been defined. It was planned to measure all variables (emission, meteorological variables) with a time resolution of one hour and a space resolution of 1 km x 1 km. In detail, the following quantities had to be determined:

- Distribution and strength of emission sources existing in this area:

  An emission inventory is to be set up, which exceeds in its space and time resolution as well as in its accuracy and completeness all former emission surveys for this area.

- Atmospheric flow field as a function of synoptical conditions:

  The flow fields depends mostly on the large scale weather situation, which is recorded by the German Weather Service through synoptic analysis. Through additional aerological soundings, the specific meteorological conditions were documented. Furthermore, various measurements of meteorological variables were carried out close to the ground.

- Concentration field of the sulphur-dioxides:

  Through airborne-measurements, ground-measurement stations and temporary mobile measurement facilities during the experiment, the three dimensional concentration field was defined.

- Oxidation-reaction:

  An improved estimation of the mass balance of SO_2 takes these oxidation reactions into account. For the quantitative determination of these reactions, the following gaseous constituents were registered during the experiment, aside from SO_2: ozone, NO, NO_2 and CO. Besides these, sulphate, nitrate and chloride and, at several measuring point, even other particulate pollutants were measured.

- Deposition of sulphur-dioxides:

  For the mass balance of pollutants, the ground sink has to be considered as well. Therefore, the deposition of SO_2 was measured at two sites.

- Model simulations:

  For the modelling of the three-dimensional flow field, a mesoscale model is employed, which is based on the anelastic approximation of the Navier-Stokes equation. The non-hydrostatic mesoscale model is particularly suited for the simulation of the flow over inhomogeneous terrain with a spatial resolution of the order of one kilometer. At present, modelling chemical reactions of SO_2 is not included, but will be added in the near future.

3.2 Organisation

TULLA was carried out in cooperation with several research groups from universities, large research establishments, authorities of the Land and of the State as well as private companies. The experiment was mainly financed by PEF (Project European Research Centre for the Maintenance of Clean Air at the Nuclear Research Centre Karlsruhe). In addition, the measurement programme was substantially supported by the following organisations: Commission of the European Communities, Institute for Environmental Protection of the Land Baden-Württemberg (LFU), Federal Environment Office (UBA), Enterprises for Energy Supply in Baden-Württemberg and the German Weather Service (DWD). The staff assignment for the individual sectors can be taken from tab. 3/1.

In 33 measuring teams, more than 120 scientists from 8 countries participated in the TULLA-campaign. The measuring teams and their contributions are listed in tab. 3/2.

3.3 Definition of the Measuring Phases

It was planned to carry out a maximum of five measuring phases during the time interval from March 18, 1985 to March 29, 1985. For the planning of the measuring strategies, three weather types were classified (see tab. 3/3). A further classification, depending only on the wind direction, was necessary for the planning of aircraft measurements and their flight patterns (see tab. 3/4). A total of four measuring phases was performed during the TULLA experiment, see tab. 3/5.

4. Documentation of the Large Scale Weather Situation (contributed by Dipl.-Met. M. Jaeneke)

This section is a description of the weather development several days before, and particularly during the TULLA experiment. Figs. 4/1 to 4/47 show the daily weather situations. Most of the information has been extracted from the European Weather Report. (Surface charts at 12 UTC, 300 hPa at 00 UTC). During the TULLA experiment, the synoptic weather development are complemented by detailed weather charts based upon stations in Baden-Würtemberg. Charts from radio sonde ascents, from Payerne/Switzerland, Stuttgart, Munich, Lindenberg, Meiningen and Viennà/Austria are added to the synopsis.

4.1 Synoptic Weather Conditions from 14th - 17th March 1985

A few days before the TULLA experiment, the weather situation was characterised by the development of a cold air formation and trough situation over Central Europe. On 14th and 15th March, two cold fronts from an expanding low pressure system over Scandinavia and the North Sea passed Germany and France and finally reached the Alps and the area of the Mediterranean Sea, carrying maritime polar-air with them.

The southern and south-easterly directed cold air advection substantially intensified an already existing trough at higher levels over the North Sea and Central Europe. Accordingly, a new surface depression of 995 hPa was built up below the front side of the trough until March 17 in the area of Adria/Gulf of Genoa, which merged into a partial low, moving from the British Isles to Central Europe. At the same time, an old low pressure system quickly weakened over Scandinavia and the North Sea. Already on March 17, a high pressure zone developed on the front side of a distinct altitudal ridge over Iceland as the result of a massive negative vorticity-advection (NVA), reaching from the British Isles and Scandinavia to northern Russia. At the same time, a precipitation field, caused by upslide motion and belonging to the new south-eastern low pressure complex, stretched from the east to the entire south-western part of Germany. In the meantime, the temperature in the maritime polar air decreased to -35°C at 500 hPa and to -7°C at 850 hPa. As a result, the precipitation fell as snow, even in the low elevations of the Rhine Valley, and a complete snow coverage began to build up.

4.2 Synoptic Weather Condition on Monday, March 18, 1985

The snow-fall situation reached its climax on March 18, 1985. While in the north European high pressure zone surface pressure increased to 1025 hPa, the upslide precipitation in Southern Germany continued at the northern flank from the double low, now reaching from Central Italy to the Northern Balkan. This was due to a cut-off development within a strong upper level trough, in whose course an independant upper level low formed over the Adria. Positive vorticity-advection (PVA) on the eastern and northern flank at upper levels and the increasing warm air advection (WAA) from the south and south-east caused a strong lifting process. This, in turn, was sharply bordered over France by a negative vorticity-advection (NVA) on the back side, by an upper level trough and a high over the Adriatic as well as by a cold air advection (CAA), so that most parts of France were cloudless, due to subsidence of the air. A quasi-stationary warm front over Eastern Central Europe marked the upgliding process over south and south-west Germany on the surface weather chart. With temperatures close to the freezing point, the snow coverage thus quickly grew. With weak to medium north-to north-westerly winds, this increase was extremely intensive, especially in the blocking area of the Swabian Mountains. Therefore, on March 19th, a total snow height of 30 - 50 cm was measured at the northern side of the Swabian Mountains, and of 30 - 75 cm in the Southern Black Forest. At lower elevations of Upper Swabia, in the Upper Rhine Valley north of Karlsruhe, and in the Neckar-Valley, the snow height measured mostly 10 - 15 cm.

4.3 Synoptic Weather Condition on Tuesday, March 19, 1985

On March 19, the main core of the South-East European low complex shifted to the East. In the morning, the centre of the low was over Middle Adria and Jugoslavia, at noon over the north of Greece. The upslide precipitation was now less intensive and covered mainly Northern Europe and Jugoslavia. Snowfall diminished rapidly over Baden-Württemberg and ceased completely in the afternoon. In connection with this, the advection analysis showed retreating PVA and WAA areas, and expanding areas of NVA and CAA, moving from France towards south-west Germany. The beginning subsidence caused the appearance of a flat high pressure ridge, due to divergence of the low level flow and, apart from the end of precipitation in the afternoon, first signs of cloud-clearance. Due to a weakening of the horizontal pressure gradient, the wind practically ceased on March 19, 1985 and lost its principally north-to-north-western direction. After temperatures of -2°C to -4°C during the night, the temperature rose to 1 to 3°C during the day, because of sunshine in the lowlands.

4.4 Synopthic Weather Condition on Wednesday, March 20, 1985

The low, which had reached with its main core Northern Greece the day before, finally drifted to the Black Sea by noon of March 20th. The strong North European high now showed a distinct core of 1030 hPa over South Eastern Finnland. Although its wedge, pointing to the North Sea and North Germany, was levelling off on the whole, the high pressure influence prevailed temporarily over South-East Germany. Two processes were involved:

1. a re-arrangement of the flow conditions at higher levels, and
2. a new low pressure development over the North Atlantic and the western Mediterranean Sea.

Until March 20, 1985, the compact upper level-low over the Adrian Sea extended to a long drawn low pressure zone from Turkey to Central and West Europe. Its axis now slowly moved in a north-eastern direction, so that south-west Germany increasingly came under the influence of NVA at higher levels. Therefore, subsidence continued. The departing movement of the low pressure zone was supported considerably by being connected with a trough over Iceland at high altitudes. In the meantime, a strong low pressure appeared in this area, which originated on the Southern American coast and lowered its pressure core from 985 hPa to 965 hPa within two days. The fronts of the intensive Icelandic low quickly approached Spain and Portugal. The front, moving rapidly in an eastern direction, was considerably blocked through the North European high. Down-stream of the Icelandic storm low, a further low had developed the day before in the area of the Biscay. Around midday of March 20th, the front reached the sea area between the Balearic Islands and Sardinia, after increasing rapidly. As is shown by satellite pictures, its dense clouds (PVA in the altitude, WAA) dominated the Mediterranean area, but were unable to prevail north of the Alpine ridge.

The layers stabilized considerably as a result of the incessant subsidence over Baden-Württemberg at that time. According to the soundings at Payerne and Stuttgart, isothermal vertical temperature structures above 850 hPa developed already during the night. Single inversions crystalized with progressing subsidence.

Except in the southern Rhine Valley, low stratus clouds existed in the early hours of the day, which disappeard quickly, as did the fog over the Danube area. Consequently, sunny weather prevailed, with practically no exception. Only towards evening, local fields of cirrus-clouds appeared.

The temperatures, which at night ranged mostly between 0 and -4°C and were even slightly lower in mountainous areas and at the Danube, rose to a maximum of 4 - 8°C. Therefore, the snow started to melt in the lower areas. The wind was predominantly weak, and blew, due to orographical influence, from different changing directions. This was the result of the extremely slight horizontal air pressure gradients on the rim of the North European high on that day. Apart from early mist, visibility in the low areas lay mostly between 5 and 10 km, in the low mountain range clearly higher.

4.5 Synoptic Weather Condition on Thursday, March 21, 1985

On March 21 and 22, the large scale weather situation increasingly changed to the type "low over the British Isles". Thereby, the weather became variable, but was nevertheless connected with the influx of milder maritime air masses from the central North Atlantic.

By noon of March 21, the Atlantic storm low, which had arrived south of Iceland the day before, reached the Irish Sea and slightly reduced its core pressure by 10 hPa to 975 hPa. Its long stretched, still occluding frontal system extended to western France during the night and moved relatively quickly in an eastern direction during the day, so that the occlusion front reached the border of Baden-Württemberg in the evening. The further development was substantially influenced by a retrogradal shift of the European upper level high: While the old low pressure zone on high altitudes over central and south-east Europe diminished completely during its shift towards the north-east, CAA built up a new trough at the backside of the British low over France. This finally joined the altitudal cyclone belonging to the Mediterranean low, thus building up a trough system from Ireland to Tunesia. On its front side, the altitudal current over Central Europe turned south during the day, and therefore the continuing eastern shift of the occlusion front towards France was extremely slowed down. At the same time, the Mediterrenean low diminished greatly. At noon of March 21, it lay in front of central Italy with a core pressure of only 995 hPa.

In the early morning, cloudless weather had been registered in large parts of the Federal Republic. Nevertheless, in the course of the morning high and medium level cloud fields within the flow at the Eastern side of the trough increasingly encroached Baden-Württemberg from the south as well as from the west. Parallel to this, the dense fog at the Danube and at Lake Constance dissolved during the morning. Satellite pictures show that, due to southern currents in this altitude, a more or less broad Foehn-gap was developing in the upper clouds of the northern Alpine border. In more northern regions, slight precipitation was observed.

Compared to the day before, the temperatures continued to rise - in the Upper Rhine Valley to 8 - 10°C, at the Neckar to 4 - 6°C, and in the region of Upper Swabia/Danube to 3 - 5 °C. During the relatively clear night, wide spread frost between -1° and -7°C had been registered. Despite a slight increase in the horizontal pressure gradient, the surface winds remained relatively weak, coming mainly from eastern directions and turning to south-west later on while moving from West to East.

4.6 Synoptic Weather Conditions on Friday, March 22, 1985

The influx of relatively mild maritime air masses from south-west, which commenced the day before, still increased on March 22, 1985.

While the core of the now prevailing circulating low over the Irish Sea shifted only slightly towards Southern England and, as the result of a diminishing tilt, filled up as expected to 985 hPa, its occluding front moved slowly over Baden-Württemberg in an eastern direction during the night, having no considerable weather effects. Only in the south-west of the country, light precipitation was observed (e. g. Constance 1,0 mm). Besides the Foehn-effect, the fact that the flow at the eastern side of the trough was slightly confluent and therefore showed practically no PVA was responsible for the weakening of the front. The line of the retrograde upper level trough was oriented at 00 UTC from the British Isles, over eastern France and from Italy to Lybia. After the weak occluding front had passed, the weather cleared up in most parts of Baden-Württemberg around noon. The wind changed temporarily from south-south-west back to south-east-east. This change of the wind direction was caused by the advancement of another occluding front from France. This front emerged from a wave, which, coming from Newfoundland the day before, had been included in the back side of the British low. Now, it rapidly occluded on its way to western Europe. During the afternoon, clouds appeared together with this front, but only local slight rain (Constance 0.5 mm) occurred till 18 UTC in the south-west. Following the front, the wind changed to south-west in the Rhine region and the Black Forest, which intensified in open mountainous regions (Feldberg 18 UTC 25 knots). During the night of March 22, 1985, for the first time since the beginning of the experiment the temperatures remained above 0°C in the Upper Rhine region, whereas in mountainous regions, at the Neckar and the Danube rivers, slight frost of 0°C to -3°C was registered. During the following day, the temperature reached maximum values between 13°C to 15°C in the area between Mannheim and Basel, while in the remaining lowlands values between 10°C to 12°C were observed. Due to the high temperatures, the entire snow blanket in the Upper Rhine region had disappeared by evening and remained only in parts of Upper Swabia/Danube as well as in the Neckar region.

4.7 Synoptic weather condition on Saturday, March 23, 1985

At noon of March 23, 1985, the controlling low lay over the British Islands, after a slight northerly shift with a pressure minimum of 990 hPa at the central English North Sea coast. In the meantime, the occluding front had reached the eastern parts of Central Europe. By 00 UTC, the upper level trough of the low-level British low had advance with its southern part to Greece. Now, its centre slowly moved towards Germany. Therefore, the air within the trough reached Baden-Württemberg during the day. The temperatures at the 500 hPa surface, which at had still been around -27°C, decreased to -32°C till the following night (24th March 1985). The slow destabilisation of the vertical air layers, which had started the days before, was consequently accelerated. The scattered clouds changed noticably to convective character. In the Rhine Valley and the Black Forest regions, first light showers occurred. Satellite pictures, which around noon showed cellular clouds advancing from western Europe to about 10°E, indicated this destabilisation as well. Visibility increased generally to 20 - 40 km within the fresh maritime air. In comparison with the day before, the daily temperatures decreased to 10 - 13°C. From the stations in the lower elevations, only Ulm and Stuttgart airport reported slight frost at night. On March 23, 1986, the wind blew quite homogeneously from south-west, in parts even from West, at a moderate strength.

4.8 Synoptic Weather Condition on Sunday, March 24, 1985

On March 24, 1985, the destabilisation of the vertical layers over Germany reached its maximum. The British low had shifted only slightly and had reached the Scottish North Sea coast at noon with a core-isobar of 995hPa. The line of the upper level trough was oriented from north-west to south-east, and was now situated directly over Scotland. Upper-level winds were slowly turning from south-west to west. The vertical temperature profile of the radio-sonde showed a deep conditionally unstable layer. Therefore, after a partially clear sky during the night, convective clouds developed during the day as a result of a strong low-level warming of the air. Especially in the evening and during the night, showers and thunder storms were observed in the Black Forest area (Feldberg, Karlsruhe, Klippeneck). Considerable precipitation was only reported by the stations Freiburg (5 mm), Feldberg (6 mm) and Ulm (4 mm). As is shown by the satellite pictures, cellular shower clouds covered the entire area of the upper-level trough over Germany and France. As the horizontal gradient of surface pressure decreased in comparison to the day before, the winds remained weak, coming mainly from south to south-west. Only in the open mountaineous areas windspeeds of 15 - 25 knots were observed. With maximum values of 9° - 12°C, the temperatures differed only slightly from those of the day before. Only in mountaineous areas and in the south-east of Baden-Württemberg slight frost occurrd during the night. Visibility remained good (20 - 40 km).

4.9 Synoptic Weather Condition on Monday, March 25, 1985

On this day, a transition from the large scale weather type "Low British Isles" to the "cyclonal-westerly" situation set in, which lasted till the end of the TULLA experiment. This transitional situation led to a short stabilization and an anti-cyclogenesis of the weather situation for Baden-Württemberg. In the evening of March 24, 1985, pressure started to rise, thus building up a flat high at lower levels. This pressure rise was caused by NVA at the backside of the Upper-level trough moving slowly eastwards. Furthermore, this post frontal effect was strengthened by WAA, which caused an increase of the consecutive upper-level trough amplitude. Thus, Baden-Württemberg was affected by subsidence, which at that time could not be neutralized by WAA as a lifting mechanism at the front side of the upper-level wedge. The upper-level trough moving eastwards with its unstable maritime air made itself felt only through isolated showers during the night (only the weather station Öhringen reported light precipitation after 06 UTC).

The new Cu-clouds, which had formed in the morning at partly cloudy and sunshine conditions, eventually flattened off more and more. The transition to more stable layers was indicated by a comparison of the radio-sonde ascending at night of Stuttgart/Payerne (unstable) with Lyon/Paris (stable with an inversion above 800 - 750 hPa). Furthermore, this was evidenced by satellite pictures, which showed cumulus clouds covering Central and Eastern Europe as well as a mainly cloudless zone over South-West Germany. In the meantime, the large scale pressure and flow field over the Atlantic and Western Europe changed. The old controlling low pressure system over Scotland was absorbed more and more by a new, stronger low-pressure activity over the Atlantic and the Biscay. By noon, a new low, that had reached Western Biscay the day before, arrived at the south-west exit of the English Channel. It had changed its core pressure form 1000 hPa to 985 hPa within 24 hours. Its distinct eddy-structure became particularly clear on the satellite pictures. The low fronts, which had moved to France in the early hours, occluded quickly and reached Baden-Württemberg in the evening in a much weakened form. By noon, the approaching occlusion made itself felt through the appearance of high and mid-level clouds. In the evening, the cloud base in the Rhine and Black Forest regions went down to a lower level. But no precipitation was observed before 18 UTC.

During the day, the wind blew mainly from south to south-west, but turned back to south-east in the afternoon, obviously under the influence of the approaching front (isobaric and isallobaric effect). Winds remained generally weak, only the Feldberg showed a continuous south-westerly wind of 20 - 30 knots. After a night without frost, temperatures rose to 14° - 16°C as a result of stronger sunshine (in the region of Upper-Swabia 10 - 12 hours of sunshine) and the influx of warmer air. Visibility was good to very good with practically no exception, reaching even 50 km in mountaineous regions.

4.10 Synoptic Weather Condition on Tuesday, March 26, 1985

The weather situation of March 26 and 27, 1985, was characterized by a trough building up with its front side over Western and Central Europe, so that the weather development became increasingly cyclonic. The low over the English Channel of the day before decreased to 995 hPa and advanced to the southern North Sea by noon of March 26, 1985. Its occlusion front crossed Baden-Württemberg during the night with only slight weather activity (amount of precipitation mainly less than 1mm, at the Feldberg 7 mm). The follwing upper-level trough with small wave length also became visible in the ground pressure field with a clear trough line. During the morning, it quickly passed over Baden-Württemberg. In connection with this, only north-west of the line between the Swabian-Alps and Basel single showers were observed (0.0 to 3.0 mm). More in the south, the weather remained dry and relatively sunny, due to Alpine Foehn influence in respect to a trough passage predominated by a south-western upper-level current.

The now rapidly developing pressure system and the flow field over Western and Central Europe made itself felt by a further advancing cyclone from the Atlantic, which had reached 49° N, 21° W at noon the day before and followed the preceding low at a constant distance. According to the satellite pictures, the core of this low was situated over North-Western Brittany at noon. By this time, the compact cloud bands of its occluding and cold front had reached Central France. The further development was dominated by the formation of a large scale high trough in the West: on the rearside of the low over Brittany, a flow towards the West and the North set in, while outbreaks of polar maritime air moved southwards. This constellation was enhanced by a further strong low, which developed in northern Norway during the course of the day and which, in turn, was flanked westwardly by a broad high pressure wedge, starting from Greenland to the South. The back side of the Brittany low was beginning to move southwars. Due to strong CAA, the upper-level winds over France began to turn back and consequently the crossing of the front from France to Baden-Württemberg was slowed down to such an extent during the second half of the day, that it did not reach this area by evening. The wind, which had blown steadily from the south-west in the whole country, reaching up to 15 - 25 knots and up to 40 knots in open mountaineous areas, decreased considerably in the evening and towards nightfall, as the delayed front approached. The wind turned partially back to south-east. During the night, minimum temperatures ranged from 3° - 9°C. During the day, temperatures rose again to 13° - 16°C and visibility was high in the whole country, reaching in the South extreme values of about 70 km. Without any doubt, this extreme visibility was a result of the Foehn in the Alps.

4.11 Synoptic Weather Condition on Wednesday, March 27, 1985

On March 27, 1985, the weather in south-west Germany was controlled by the beginning formation of a large scale trough over the Atlantic and West Europe. At 00 UTC, the newly formed large scale upper-level trough was extending with its trough line form the North Atlantic and the North Sea to Northern Spain and the Biscay. Till noon, the centre of the low air pressure at the ground had shifted towards Scandinavia.

Within its southern core region over South Sweden, the two lows, which were approaching from the Atlantic, joined each other. The affiliated cold front advanced slowly from the North-West to south-eastern Baden-Württemberg during the night of March 27, 1985. At the same time, the weather stations observed isolated precipitation of 2 - 5 mm, and local precipitation in the Black Forest of over 10 mm. The frontal lifting processes, which were considerably strengthened by the front side of the increasing trough (PVA in upper-levels), destabilized the layers of the maritime air masses to such an extent that thunderstorms were observed (Feldberg, Stötten)

The parallel position of the cold front to the dominating upper-level flow, led partially to wave-like deformations of the front which approached the Alps, as is clearly shown by the satellite pictures. Consequently, during the morning rain continued in southern Baden-Württemberg. In the remaining parts of the Federal Republic, the clouds cleared partially but, nevertheless, several isolated showers were observed. With the passing of a second, even stronger cold front in the late afternoon and evening, continuous precipitation set in once again. This second cold front, which at noon had appeared on the satellite picture as a wide, compact cloud band, had formed during the night of March 27, 1985, along the line Northern Germany - Benelux - Northern France. It was situated directly before the upper-level trough front and turned slowly south-eastwards. In connection with this, polar maritime air reached Baden-Württemberg in the evening. Therefore, the precipitation fell as snow in mountainous areas, down to an altitude of 700 m (m.s.l.). In addition, the influx of cold air was marked by a clear change of the wind direction from west-south-west to west-north-west. But only after the turning of the wind direction, precipitation set in. The wind speed, which ranged between 5 - 15 knots, was stationary during the whole day, except for maountainous areas (Feldberg), where considerably higher values were observed. The maximum temperature was still completely dependant on the previous cold maritime air and amounted to 11°C in the lowlands, after minimum temperatures of around 7°C during the night.

4.12 Synoptic Weather Condition on Thursday, March 28, 1985

The second cold front brought polar maritime air along, which moved towards the south-east and controlled Central Europe till noon of March 28, 1985. During the course of this development, a vast upper-level trough had reached the line Denmark - Eastern France - Western Alps around 00 UTC. During the early morning hours, it crossed Baden-Württemberg with its central line. Till noon, the post-frontal precipitation continued in southern Baden-Württemberg and fell as snow, down to elevations of 400 m a.m.s.l. During the early morning, cloudiness began to break up here as well.

In the meantime, the southern surface core of the Scandinavian low pressure system had drifted over from Central Sweden to the Gulf of Bothnia, and had increased to 985 hPa at the front side trough, as a result of the favorable development conditions. Together with a strong local low (985 hPa) west off northern Norway, it now built up a compact cyclonical block. This cyclonic development over Scandinavia faced an anti-cylonic development over south-west Europe. Following a wide spread rise in pressure over west and central Europe, a high pressure cell had originated from the Greenland high pressure wedge. It was now situated over the Biscay with a core pressure of 1025 hPa. By noon already, this wedge was extending to the northern edge of the Alps. This extensive pressure rise over west and central Europe was caused by CAA as well as by NVA at the back side of the upper-level trough drifting eastwards.

It was expected that the subsidence of the air would lead to a stabilization of the still unstable cold air. However, this process was slowed down, mainly because of the continuing upper-level cold air advection on the one hand, and, secondly, because of the diabatic destabilisation of the lower layers due to sunshine during the day on the other hand. Therefore, in many cases cumulus-nimbus clouds built up towards noon, which by afternoon rose to the tropopause and thereby caused snow showers in the whole country. However, no snow blanket built up as the overall temperatures were to high. Furthermore, the total amount of precipitation was less than 1 mm - with the exception of Öhringen, where 4 mm were observed. The noon satellite picture shows shower clouds covering Central Europe and greater parts of France. Outside the showers, visibility within the inflowing polar maritime air was relatively high, reaching values of up to 20 - 60 km. The temperature maxima reached approximately 7°C in the Rhine Valley, while in the remaining areas 4° - 6°C were observed. During the whole day, frost predominated above 700 - 800 m altitude (a.m.s.l.). West to north-westerly winds, which prevailed during the night, shifted to the West during the day and even turned partially back to south-west. They showed values of 5 - 15 knots.

4.13 Synoptic Weather Condition on Friday, March 29, 1985

Till noon of March 29, 1985, the new surface high,that had reached the Biscay the previous day, moved further south-east towards Spain - the Western Mediterranean Sea - the Alps and the Balkan. Therefore, the anti-cyclonic tendency continued, in connection with the CAA and NVA at the backside of the trough. Till midnight, the trough line had advanced to the area extending form southern Sweden and Poland to northern Jugoslavia and Tunesia.

Baden-Württemberg, and especially its southern parts, was close to the centre line of the high-pressure system. Radio-sondes of 00 UTC showed even above 700 hPa a distinct stabilization with beginning inversions. As is indicated by the ascents over France, the stabilization became effective even in the lower levels during the course of the day.

At the same time, a less favourable weather development was observed over the northern part of Central Europe, which affected the northern parts of the Federal Republic in a weakened form: The strong Scandinavian low pressure system had formed a single main core with 980 hPa in its centre and was now situated in front of the Norwegian coast. At its southern flank, the air flow turned back to west and as a result milder maritime air moved eastwards over the British Isles and North Germany. The still active process of NVA at the backside of the trough was overcompensated by the effects of this warm air advection. Therefore, not only a dense cloud field developed over North Germany, but local continous rainfall set in as well. Satellite pictures confirmed that only northern and central parts of Baden-Württemberg were touched by this new cyclonal development. North off the line Karlsruhe - Stuttgart - eastern Swabian Alps, a closed Sc/Ac cloud field with sligh local rain lasted during the whole day. In the South, medium and high clouds prevailed with a changing degree of coverage. In the evening, cloud conditions improved in the North. In general, visibility ranged between 10 - 40 km, temperature maxima were higher than those of the previous day with values of 6° - 10°C especially in the South. The wind was moderate to fresh (10 - 20 knots), came from south-west to west and abated immensely in the evening.

5. Emission Inventory

For the preparation of the emission inventory, a research group headed by Prof. Voss (Stuttgart) is responsible. The inquiry of the emission inventory contains data, which were not only recorded during the TULLA experiment but have partly been collected before the experiment and afterwards. The aim is to prepare an emission inventory for SO_2 and NO_x for the Land Baden-Württemberg with an hourly resolution of a 1 x 1 km screen.

The SO_2 and NO_x discharge form larger sources (energy consumption over 10 MW) from the conversion sector and the industry is determined throug a survey which collects, as far as possible, directly the hourly mean values from the measuring instruments or by means of emission factors (sample measurement) calculated from hourly values of primary energy supplies. With this procedure, approximately 60 % of all SO_2 an NO_x emissions have directly been registered during the measuring campaign and the sources have been precisely located within the area of the emission inventory. As no continous measurements exist for the remaining 40 % of the emissions caused by smaller industrial installations as well as by small consumers, private households and traffic, these emissions are determined in the following way: Models,which are based on the analysis of statistical data and which take daytime, temperature variations, wind speed, mean sun irradiation as well as further boundary conditions (day of the week, time of year, holidays, etc) into account, are used in order to determine the amount and the distribution in space of the hourly energy usage of the various energy carriers and to derive emission values from them.

6. Meteorological Measurements

6.1 Radio-Sonde Programme

At two stations, radio-sonde ascents were carried out within the frame of the routine synoptical network (see Figure 6/1).
At the DWD-station Stuttgart, Graw sondes (type M 60) were used, while the Military Geophysical Service (Geophys.) in Neuhasen o. Eck, near Tuttlingen, employed sondes manufactured by the Sprenger corporation. The ascending speed of approximately 300 m min^{-1} were set by the routine soundings. The ascents carried out during the TULLA measuring phases are listed in tab. 6/1.

Dr Walk was the head of the group responsible for obtaining, handling and checking the radio-sonde data.

6.2 Structure-Sonde Programme

Several structure-sondes (ascending rate 150 m min^{-1}) were used in order to improve the horizontal resolution of the observations as well as the vertical resolution of meteorological variables (Figure 6/1). At six stations, Graw sondes (type TDFS 77 Q) were started, while only in Karlsruhe Sprenger sondes (type E Ø 74, PTT O 400) were employed. The ascents were tracked by radar at the stations Bad Mergentheim, Stuttgart and Neuhausen o. Eck. The stations Mannheim, Karlsruhe, Freiburg and Biberach followed the ballons with theodolite systems. Double theodolite systems were generally used, with the exception of Karlsruhe. During the first measuring phase of March 20 and 21, pilot balloons were started in alternation with structure sondes, so that the wind profiles were measured at 1.5 hourly intervals. Temperature and humidity profiles were recorded every three hours.

The time schedule for the TULLA measuring phases is contained in tab. 6/2. Dr. Walk was responsible for the collection of these data.

6.3 Tethered Balloons

The tethered balloon system with its sonde is a stationary system as opposed to radio sondes and structure sondes. It is also limited with respect to the height which can be reached. However, due to the low ascending speed of about 1 ms^{-1}, the vertical resolution of the tethered balloon sonde is clearly better.

During the TULLA campaign, three tethered balloons were used. See fig. 6/1 and tab. 6/3.

Dr. Walk was responsible for the tethered balloon in Ulm, Dr. Ahrens for the one in Tauberbischofsheim and Dr. Gassman for the Würenlingen balloon.

6.4 Sodar

With a Doppler-Sodar instrument (Sound Detection and Ranging), additional information concerning the wind profiles of a site near Ravensburg (fig. 6/1) was collected. These are the vertical profiles of back scatter amplitude, wind speed, wind direction and the standard deviation of the vertical wind speed. Dr. Thomas was responsible for the Sodar data. Tab. 6/4 shows the operation data as well as the action data of the Sodar.

6.5 Tower Measurements

In Baden-Württemberg, five meteorological towers with a minimum height of 100 m are available in the Rhine Valley. Near the planned second nuclear power plant in Obrigheim (fig. 6/1), a 163 m tower is located. Tab. 6/5 contains a list of the most important data of all towers and a list of the instruments used. The data is recorded automatically and continuously, as was the case during the TULLA measuring phases too. Mr. von Holleuffer-Kypke was responsible for the collection of the tower data.

6.6 Surface Meteorological Measurements

In Baden-Württemberg, numerous ground stations for the collection of meteorological parameters are operated by different institutions, for example: the German Weather Service (DWD), the Institute for Environmental Protection of the Land Baden-Württemberg (LfU) as well as by various power plants and industrial plants. All stations are listed in fig. 6/2.

The DWD net includes 2 weather offices (Stuttgart and Freiburg), 2 weather observatories (Mannheim and Konstanz) as well as 7 weather observation stations (Öhringen, Karlsruhe, Stötten, Freudenstadt, Ulm, Klippeneck and Feldberg). At present, the LfU operates 20 automatic stations in its air pollution network. Every 0.5 hour, the data is recorded. The stations and the measured meteorological components are listed in tab. 6/6.

7. Further Activities for the Determination of the Atmospheric Flow

7.1 Tetroon-Flights

Apart from the Eularian mesurements of the ground stations, of towers and radiosondes for the recording of the atmospheric flow field within the experimental area, tetroon flights allow a Lagrangian survey of the flow. A tetroon (tetrahedral balloon) follows the air flow on a surface with constant air density; this is due to its construction. The desired flight altitude, which depends on the prevailing temperature and pressure profiles, is adjusted by means of ballast. During the TULLA measuring phases, 13 tetroons were started and tracked from four different locations. Tab. 7/1 shows the most important flight information. Mr. Vogt was responsible for the evalution of the tetroon data.

7.2 Tracer Experiments

The experiments were carried out by the Joint Research Centre Ispra and by the Institut für Meteorologie und Klimaforschung (IMK/KFK). Even though these experiments do not contribute directly to the problem of balancing air pollutants, one can nevertheless deduce turbulence parameters from the concentration values.

In these experiments, an inert chemical tracer with an emission rate of approximately 28 g/s was emitted. SF_6 was used as a tracer. The emission was effected through the 140 m high chimney of a municipal heating power plant, while westerly wind conditions prevailed on March 23 and 25, 1985. On March 28, the emission took place from a 10 m high source without buoyancy, while the wind came from a north-westerly direction.

At the lee side of the source, air samples (several samples, each lasting 0.5 h) were taken at specific points, whose tracer concentration was afterwards analysed in the laboratory. These samples were collected at approximately 60 different measuring points, which were distributed along three arcs. Dr. Gaglione was responsible for the evaluation of the air samples. Tab. 7/2 containes the information concerning the emission and the sampling times.

On March 23 and 25, 1985, SF_6 samples, which were later analysed in the laboratory, were taken from the NILU-aircraft (Dr. Berg) at 20 checkpoints along the flight pattern. At three checkpoints, the SF_6 concentration was clearly higher than the background.

The distance between these checkpoints and the emission point was between 20 km and 140 km. The flight altitude was approximately 500 m above ground.

7.3 Analysis Data of the German Weather Service

In addition to the meteorological measurements, the data set is complemented by further synoptic data, which have been collected by the German Weather Service. Apart from the existing data, which is published regularly in the daily weather charts, objective analysis are available for the time interval of March 15, 1985, 00Z to April 1, 1985, 00Z. These analysis, which are regularly worked out by the German Weather Service, are available in two different forms in the following sizes:

1.	Grid size	254 km
	time interval	6 hours
	meteorological parameter	pressure levels
	air pressure p	ground (reduced to NN)
	height of absolute topography H	950, 850, 700, 500, 300, 200, 100 hPa
	temperature T	dto.
	components of horizontal wind speed u, v	950, 850, 700, 300, 200, 100 hPa
	relative humidity F	950, 850, 700 hPa
2.	Grid size	127 km
	time interval	12 hours
	meteorological parameter	pressure levels
	air pressure p	ground
	absolute topography H	950, 850, 700, 500, 300, 200, 100 hPa
	air temperature T	ground, 950, 850, 700, 500, 300, 200, 100 hPa

The second data set was inferred from the first set by interpolation and was initialized with the BKN-model (Baroklin) of the German Weather Service.

In addition, information is available about the size and the location of the grid points to which the meteorological values are related.

7.4 Satellite Data

The AVHRR (Advanced Very High Resolution Radiometer) of the NOAA satellites supplies pictures in five spectral ranges

0.58	-	0.68 µm
0.73	-	1.10 µm
3.55	-	3.93 µm
10.30	-	11.30 µm
11.50	-	12.50 µm

with a spatial resolution of 1 km within the sub-satellite point.

During the TULLA campaign, the satellites NOAA-6 and NOAA-9 were in operation. The data was registered at the following stations: Oberpfaffenhofen (DVLR), Bern (Department of Geography) and at Dundee (Department of Engineering and Electronics). Up to 4 scences are available per day. After a preprocessing of the data at the DFVLR, the Department of Geography of the University Freiburg prepared charts and tables of the brightness temperatures of the ground and of the cloud coverage for those pictures of larger cloudless areas, which could be classified spatially with the necessary precision. Thereby, the atmospheric influence on the brightness temperature of the ground surface was corrected with a terrain model based on radio-sonde ascents.

Prof. Goßmann was responsible for these tasks.

Tab. 7/3 contains a list of all scences included in the present evaluation.

8. Immission Measurements

8.1 Ground-based Concentration Measurements

The immission measuring network with most stations in Baden-Württemberg is operated by the LfU. This automatic multicomponent immission measuring network is predominantly used for routine observations of urban areas.

Fig. 8/1 shows the position of the measuring stations and in tab. 8/1 their co-ordinates (Gauß-Krüger-System) are listed. All stations are almost identically equipped in respect to measuring air pollutants. In tab. 8/2, the measuring components are listed. More than half of the stations convey their obtained measurment values directly in an on-line operation to the Measurement Processing Centre (MVZ) in Karlsruhe. The stations Mannheim, Karlsruhe and Stuttgart, in turn, are controlled by regional sub-centres and convey their data first to these preprocessing sub-centres, from where they are transferred to the MVZ.

For each station, the data listed in tab. 8/2 is stored in the same format on magnetic tape as 0.5 h mean values. Dr. Obländer was responsible for the data of these stations.

Apart from the immission measuring network of the LfU-BW, a large number of further measuring networks and single immission measurements exist within the TULLA experimental area. These are operated by the authorities, by research institutions or companies. Tab. 8/3 contains a complete list of the measuring stations, the contact partners, and the measuring components.

8.2 Particle Measurements

To gain further information on the distribution of air pollutants and their reaction products in the atmospheric boundary layers, eleven additional measuring stations were set up outside urban areas, where particulate pollutants as well as the SO_2 concentration are measured. Their position was orientated to the flight path of the aircrafts. These stations are marked in fig. 8/2.

Between 9:00 a.m. and 17:30 p.m., samples of up to eight half-hour mean values of the particle bound pollutants and the SO_2 concentration were taken at these stations. Tabs. 8/4 and 8/5 show the time interval of the TULLA measurements. At the station "Schauinsland" only particle collection was carried out (tab. 8/6).

Dr. Jaeschke was responsible for these measurements.

In addition to the impactor measurments (see subsection 9.4), filter samples were collected, which were analysed with X-ray fluorescence (RFA). The concentration of the following elements was determined: S, K, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Br, Sr, As, Se, Ba, Cl, Rb and V. Short time measurements (exposition duration 2 - 3 hours) were carried out at those ground stations listed in tab. 8/7. In order to characterize the immission situation during the TULLA experiment, additional filters for the sampling of time series of mean day values were added and analysed by means of RFA between March 15, 1985 and April 9, 1985 in Hohenheim and at the LfU stations Kälbelescheuer, Karlsruhe and Mannheim.

Prof. Schreiber was responsible for the RFA.

8.3 Deposition

During the Tulla experiment, measurements for the determination of the dry deposition of SO_2 were carried out at two locations, one was a glider-airfield over grassland in Linkenheim-Hochstetten, the other in a forest area at the "Schöllkopf" close to Freudenstadt. At the Schöllkopf, the terrain was complex, the local canopy 25 m high and the instruments were placed at 36.5 m.

In Linkenheim-Hochstetten, measuring teams from the University Frankfurt, of the KfK and of the Argonne Nat. Lab. worked with the gradient measuring method and with the Eddy-correlation method. In principle, all measurements between March 19, 1985, and March 29, 1985, were carried out continually. Due to technical difficulties (power failure, failure of equipment etc.), time losses occurred. Tab. 8/8 shows the measuring time table of the KfK team. Dr. Weppner was responsible for deposition measurements.

At the "Schöllkopf" the working team of the Atmospheric Turbulence and Diffusion Div. Oak Ridge, applied the Eddy-correlation method as well.

The data report consists of half-hour averages of various turbulence parameters and SO_2 concentrations, fluxes and deposition velocities measured between March 19, 1985, and March 29, 1985. Due to various weather and instrumentation problems, the data record is not continous, However, for 440 out of 504 possible half-hour periods partial data is available.

8.4 COSPEC - Measurements

A correlation spectrometer (COSPEC) is a remote sensing instrument used to determine the total content of SO_2 and NO_2 of an air column above the instrument. The measurement is based on the absorption of light by these air pollutants in a certain frequency ranges (SO_2 in the UV, NO_2 in the visible); the incident sky light serves as the source of light. The employment of COSOECs in a traveling van allows integral measurements of the air pollution of the airmasses along highway-routes.

Three correlation spectrometers were used, which are owned and operated by: a) UBA pilot station Frankfurt, Dr. Beilke; b) GFS-Ispra, Dr. Sandroni and c) the Institute of Hygenics and Epidemology Belgium, Dr. De Saeger. Tab. 8/9 contains a timetable of the measurements.

9. Airborne Measurements

Measuring activities from aircrafts can be divided into three categories:

a) 7 aircrafts for the gas measurements of SO_2, NO_x and O_3, each time in two formations.
Red formation: CEA, Goesens, NILU, TH Darmstadt
(TULLA 1 R to TULLA 1R to TULLA 4R)
Blue formation: CERL, DFVLR, University Frankfurt
(TULLA 5B to TULLA 7B)

Tab. 9/1 contains a list and a detailed description of the measuring instruments used in the aircrafts.

b) 1 Jet - HS 125 (MPI Mainz/Fraunhofer Institut Garmisch-Partenkirchen) for vertical profiles of the tracer substances CO, O_3, NO, NO_y, H_2O, CH_4, CFM and KW.

c) 1 motorglider and a single motor twin-seat machine, mainly for meteorological parameters.

9.1 General Information about the Red- and Blue Formation

The following principle determined the planning of the flight patterns: The inflow and the outflow of the pollutants within the experimental area is to be completed in the shortest possible time.
As a consequence, 8 flight routes have been determined; those which are marked as L1, L2 and L3 run almost parallel to the Rhine in a north-south direction, those which are marked as T1A, T1B, T1C, T2 and T3 run in a crossway direction (see chart 9/1).

Along the flight routes, certain time checkpoints were fixed. Each checkpoint was determined on the enclosed map in respect to the radial axis or to DME reports by radio navigation systems. As a rule, a distinct ground mark was chosen as a checkpoint. The time of the crossing of theses checkpoints was noted by the crew.

The exact description of the flight routes can be taken from tab. 9/2 and 9/3.

In tab. 9/4, the geographic co-ordinates of the checkpoints are listed from 1 to 55.

The flight pattern to be flown was dependant on the prevailing wind directions of that day. A total of three flight patterns had been prepared, as can be seen in figs. 9./2. to 9/4. The relation between flight pattern and wind direction can be taken from tab. 9/5. The respective pattern was flown by the two formations (red and blue) at different altitudes. The flight velocity of the two formations was 120 kt TAS (true air speed).

9.2 Flights Performed by the Red- and Blue Formations

On six days, measuring flights were carried out. The timetable and the arrangement of the aircrafts during these flights are listed in tab. 9/6. The take-off and landing times as well as the prescribed altitudes are given in tab. 9/7. Therefore, tab. 9/6 combined with figs. 9/5 to 9/9 allows the determination of the flight altitude of each aircraft at the respective checkpoint.

9.3 Sampling of Particulate Components

Apart from the continuously operating instruments measuring the gaseous pollutants, pumps were used in the aircraft, which accumulate particles (SO_4^{2-}, NO_3^- , Cl^-) on filters. Accumulation times range between 15 and 30 minutes, which corresponds to integral measurements over a distance of approximately 60 to 110 km at a flight speed of 120 kt. Tabs. 9/8 and 9/9 give a survey of the flight patterns and of the approximate accumulation time for the filter.

9.4 Impactor Measurements

Five-staged mini-impactors were used in two aircrafts (University Darmstadt, Goesens) and 7 ground stations. The evaluation of these impactors by means of laser-microsonde mass analysis furnished information about the chemical composition of the particle material in different size categories at the different locations and during different flight phases at two different altitudes (see tab. 9/10).

Prof. Wieser was responsible for the evaluation of the mini-impactors.

By analysing the samples by means of X-ray fluorescence, the following elements were analysed: S, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Br, Sr, As, Se, Ba, Cl, Rb and V. These analyses were carried out by Prof. Schreiber.

9.5 Jet - HS 125

This aircraft was based at Stuttgart Airport. Prof. Seiler was responsible for these measurments.

A total of 4 measuring flights was carried out, which lasted, including the transfer (the home base is Köln Airport), approximately 20 hours. The operation timetable can be taken from tab. 9/11. During all flights, the tracer gases CO, O_3, NO, NO_y and H_2O were continuosly measured. In addition, air samples were taken during the first three flights, which were transported to Mainz the same evening in order to be analysed with respect to the contents of chlorfluormethanes, hydrocarbonates as well as N_2O, CH_4, CO and H_2. Due to analysis problems, air sampling was no longer possible during the last flight.

The above mentioned tracer gases were determined during quick descents and ascents of the aircraft. The descending and ascending rates of the aircraft ranged between 8 - 10 m sec^{-1}. For aeronautical reasons, these "Dolphin" flights were carried out under visual flight rules, thus allowing altitudes between 500 feet to 9500 feet above ground.

As four to five minutes were needed for each vertical profile, up to 40 vertical profiles could be measured per flight. From this, the vertical and horizontal two-dimensional distributions of the measured tracer gases can be calculated.

9.6 Motor glider ASK-16

A motor glider ASK-16 based at Birrfeld Airport, close to Baden-Schweiz, was used. Dr. Gassmann was responsible for these measurements.

The measured elements were temperature, relative and absolute humidity, ozone and flight altitude at intervals of 1 second. The motor glider measurements were carried out along a west-eastern traverse, on the southern border of the experimental area between Rheinfelden-Schopfheim and Romanshorn-Immenstaadt (fig. 9/10).

The flight altitude was between 150 - 250 feet above ground, whereas spiral flights up to 3000 m NN were carried out at the turning points, see tab. 9/12. The operation times are listed in tab. 9/13.

9.7 Single Motor Aircraft Bölkow 207

Between the radio-sonde stations Karlsruhe and Mannheim, measurements of the temperature and humidity fields were carried out by the "Akaflieg" Karlsruhe with a motor plane Bölkow 207. Mr. Walter was responsible for these measurements.

The flight route was on a straight line between the TULLA radio-sonde stations Karlsruhe and Mannheim, with a length of 54 km, rwk 014° (194°).

Fix points along the route were:

1) Institute for Environmental Protection of the Land Baden-Württemberg, Karlsruhe-Neureut
2) Linkenheim Airport, 500 m east of the hangar
3) KKW Philippsburg, 1 km east of the cooling tower
4) Refinery Speyer
5) Herrenteich Airport
6) Rohrhof, a village south of Mannheim (artificial lake in a gravel pit)
7) Weather Observatory Mannheim (district of Vogelstang).

In the area of Philippsburg, one vertical profile was flown as well as three horizontal traverses. Two traverses were to be flown beneath a possibly existing inversion, one was to be flown above this inversion. This flight profile is schematically depicted in fig. 9/10. The highest flight traverse was to be 200 m above the top of the inversion, the middle one was to be beneath the inversion and the lower traverse was not to fall below 250 m GND.

If there was no inversion, traverses were flown at a respective altitude of 250 m, 600 m and 900 m GND. Flights were performed at 4 days, see tab. 9/11.

The measured data were recorded by a data logger AK4 of the "Akaflieg" in Karlsruhe. The scanning rate is 4 Hz for T, T_f and p.

10. Topographical Data

The existing topographical data is based on an investigation into the topography of the entire Federal Republic of Germany, which was set up by the telecommunications engineering department of the Federal Post Office (Deutsche Bundespost) in the years 1965 - 72.

The investigation area covers 5°50′ to 14°0′ longitude and 47°12′ to 55°0′ latitude north.

The topographical heights were maually digitized from maps with a scale of 1:25000. A land use index of the area was inferred from maps with a scale of 1:50000. The basic grid consists of a 5′′ x 5′′ screen. This screen was changed from geographic co-ordinates to a 101.6 m x 101.6 m screen within the UTM net for zone 32 U. The KfK commissioned topographical data in a 5 x 5 km^2 screen for the area of the Federal Republic of Germany from the IABG, the original administrator and user of these data files. The co-ordinates on the south-western rim of this screen are 6°3′41′′ east, 47°10′4′′ north. From this screen, a smaller one was chosen for the area of Baden-Württemberg (fig. 10/1), which is bordered by the following co-ordinates:

47° 23′ 34′′ N

49° 49′ 22′′ N

7° 23′ 7′′ O

10° 25′ 48′′ O

This means 55 crossing points in the north-south direction and 47 in the west-east direction.

The land use index is divided into 8 characteristic categories: large residential area, small residential area, forest, bush, mountain pine forest, dry agricultural soil and sand, wet agricultural soil, meadows and moor, water (fresh and salt water).

At present, a refined 1 x 1 km^2 screen for the area of Baden-Württemberg as well as the completion of the 5 x 5 km^2 data file at its borders (Vogese mountain range) is ordered.

11. List of Addresses

Tab. 11/1 contains a list of all participants in the TULLA experiment.

Table Index

Figure Index

Overall scientific responsibility	Fiedler
Emission	Friedrich
Meteorology	Fiedler Walk
Tracer and Tetroon-experiments	Vogt
Aircraft-measurements	Jaeschke
Aircraft logistics,-navigation	Schufmann
Air chemistry	Jaeschke
Immissions - gaseous pollutants	Obländer
Immissions - reaction-products	Jaeschke
Advisory activity in chemistry	Filby
Simulation of models	Fiedler
Coordination of the experimental contributions of the CEC activities	Stingele
Overall coordination	Vogt

Table 3/1: Members of the management group and their responsibilities

Institute	Person responsible	Contribution
Belgien		
Institute for Public Environmental Research Brüssel	de Saeger	Cospec Fahrzeug
Studiecentrum voor Kernenergie Centre d'Etude de l'Energie Nuclaire Mol	Vanderborght	Tracer Experiment
Bundesrepublik Deutschland		
Landesanstalt für Umweltschutz Karlsruhe	Ahrens	Fesselballonsonde Radiosonde
	Obländer	Immissions-messungen
Institut für Anorg. und Kernchemie TU-Darmstadt	Bächmann	Flugzeugmessungen von SO_2, NO_x, O_3 und Sulfaten
Institut für Verfahrens-technik und Dampfkessel-wesen Uni-Stuttgart	Baumbach	Immissions-messungen
Umweltbundesamt-Pilot-station-Feldberg Offenbach	Beilke	Cospec Fahrzeug
Energieversorgung Schwaben Stuttgart	Beising	Immissions-messungen
Landesanstalt für Umwelt-schutz und Gewerbeaufsicht Mainz	Bockholt	Immissions-messungen
Institut für Kernenergetik Uni-Stuttgart	Friedrich	Emissionskataster
Institut für Phys. Geo. Uni-Freiburg	Goßmann	Satellitenilder
Badenwerk AG Karlsruhe	Häsler	Immissionsmessungen
Zentrum für Umweltschutz Uni-Frankfurt	Jaeschke	Flugzeugmessungen wie TU-Darmstadt Partikelmessungen Kalibrierung
Badische Anilin- und Soda-fabrik, Ludwigshafen	Mutz	Immissionsmessungen Meteorologische Messungen
Neckarwerke AG Esslingen	Necker	Immissionsmessungen
Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt, Oberpfaffenhofen	Paffrath Peters	Flugzeugmessungen wie TU-Darmstadt

Table 3/2: Measuring teams and their contributions

Continuation Table 3/2

Institut für Physik Uni-Hohenheim	Schreiber, Wieser	Röntgenfluoreszenzanalyse Laserinduzierte Massenspektrometrie von Partikeln (LAMMA 500)
Max-Plank-Instiut Mainz	Seiler	Flugzeugmessungen von Spurengasen bis zur Tropopause mit einem Jet
Abteilung für Angewandte Systemanalyse KfK-Karlsruhe	Schufmann	Flugzeugplanung, Navigation, Sicherheitsaspekte
Institut für Meteorologie und Klimaforschung KfK und Uni-Karlsruhe	Fiedler, Hübschmann, Nester, Thomas, Vogt, Weppner, Walk	Management, meteorologische Messungen, Radiosonden, gefesselte Sonden, SODAR, radarverfolgte Tetroon Flüge, trockene Deposition von SO_2, Modellsimulation

<u>Frankreich</u>

Commissariat a l'Energie Atomique, Saclay	Carbonelle	Flugzeugmessungen wie TU-Darmstadt

<u>Europäische Gemeinschaft</u>

Gemeinsame Forschungsstelle der Europ. Gemeinschaften, Ispra	Gaglione, Sandroni,	Tracer Experimente, Cospec Fahrzeug

<u>Niederlande</u>

Geosens, Rotterdam	Blommers	Flugzeug Messungen wie TU-Darmstadt

<u>Norwegen</u>

Norwegian Institute for Air Research, Lillestroem	Berg	Flugzeug Messungen wie TU-Darmstadt

<u>Schweiz</u>

Eidgenössisches Institut für Reaktorforschung, Würenlingen	Gassmann	Motorsegler, Fesselballon

<u>Vereinigtes Königreich</u>

Central Clectricity Generating Board, Leatherhead	Marsh	Flugzeug Messungen wie TU-Darmstadt

<u>USA</u>

Argonne Nat. Lab., Argonne	Wesley	trockenen Deoposition von SO_2
Atmospheric Turbulence and Diffusion Division Laboratory, Oak Ridge	Hicks	trockene Deposition von SO_2

Type I. Western weather situation with wind speed greater than 3m/s at 10 m height

Type II. Weather situation with easterly flow

Type III. High pressure situation with weak low level flow, no clear wind direction, distinct thermal vertical structure

Table 3/3: Weather types

Wind direction	flight pattern
210° to 270°	A
270° to 330° 45° to 135°	B
330° to 45° 135° to 210°	C

Table 3/4: Wind direction and flight pattern

Measuring phase	Beginning	UTC	CET	End	UTC	CET	Type of weather	Flight pattern
1	Wed. 20.3.85	12:0	13:0	Fri. 22.3.85	00:0	1:0	III	C
2	Sat. 23.3.85	6:0	7:0	Sun. 24.3.85	6:0	7:0	I	A
3	Mon. 25.3.85	6:0	7:0	Tue. 26.3.85	6:0	7:0	I	A
4	Thu. 28.3.85	12:0	13:0	Fri. 29.3.85	12:0	13:0	I	B, A

Table 3/5: Measuring phases during the TULLA experiment

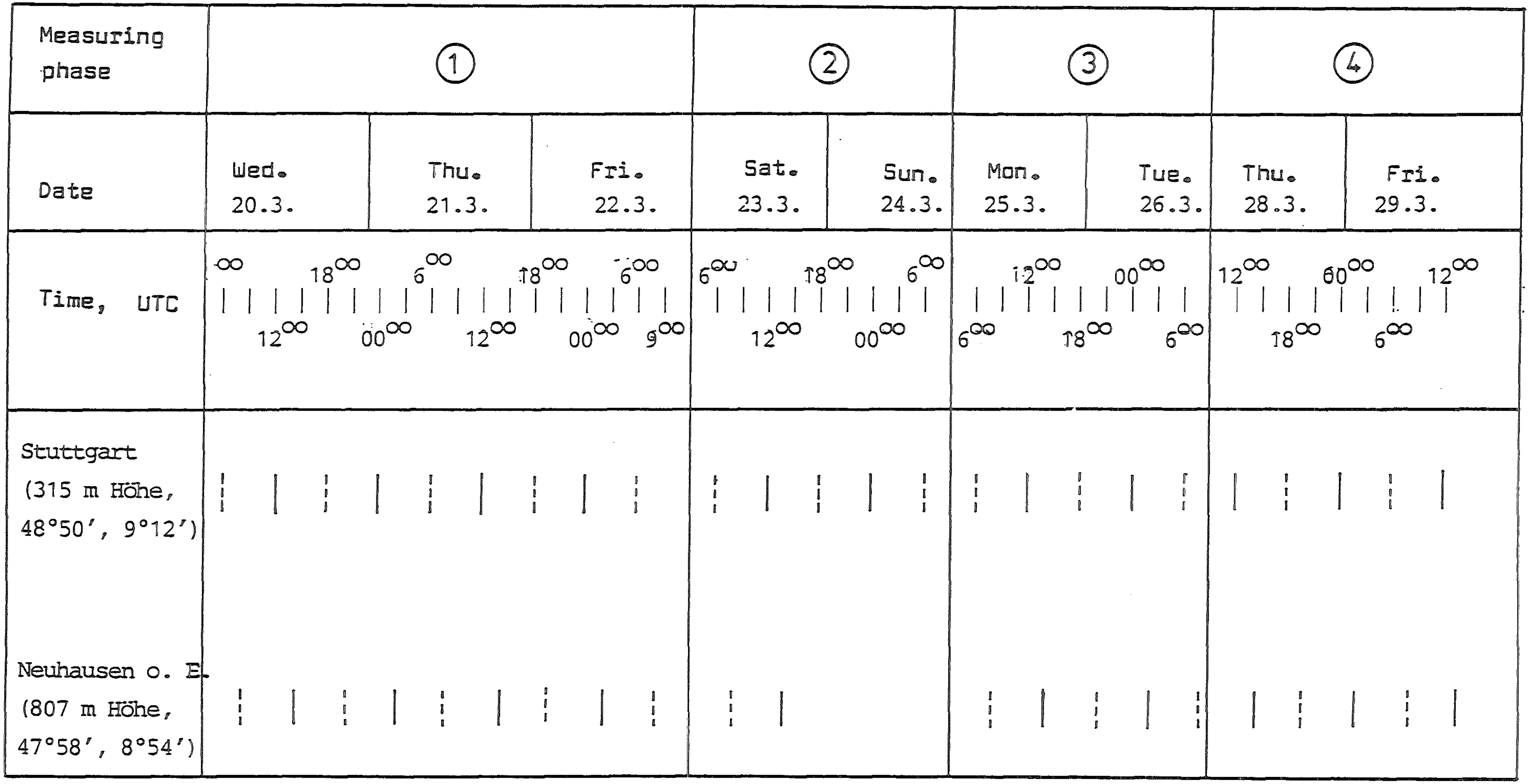


Table: 6/1 Radio-Sonde ascents

| Ascents with wind, temperature and humidity

¦ Ascents only with wind

Measuring phase	1	2	3	4
Date	Wed. 20.3. / Thu. 21.3.	Sat. 23.3. / Sun. 24.3.	Mon. 25.3. / Tue. 26.3.	Thu. 28.3. / Fri. 29.3.
	9 12 15 18 21 00 3 6 9 12 15 18 21	6 9 12 15 18 21 00 3 6	6 9 12 15 18 21 00 3 6	12 15 18 21 00 3 6 9 12
Station: Mannheim (96 m 49°31'/8°33')	SE P S P S P X P S PE SE P S PE S P SE P X P S X X	SE S SE SE S S S S	S S S S S X S S SE	S S S S S S S SE X
Bad Mergenth. (335 m 49°32'/9°52')	S P S P S P S P S P S P S X S P S P S P S P S P S	S S S S S S S S	S S S S S S S S S	S S S S S S S S S
Karlsruhe (112 m 49°2'/8°22')	SE SE SE SE SE SE SE SE SE SE SE SE SE SE	SE SE SE SE SE SE SE SE SE	SE SE SE SE SE SE SE SE	SE SE SE SE SE SE
Stuttgart (315 m 48°50'/9°12')	S P S P P S P S P S P S P S P P S P S S P S S P S	S S S S S S S S S	S S S S S S S S S S S	S S S S S S S S S
Freiburg (170 m 48°14'/7°44)	S S S S S S S S S S S S	S S S S S S S S	S S S S S S S S S	S S S S S S S S S
Biberach (584 m 47°8'/9°46')	S X S P S PE SE X X X X X X X X SE P SE P SE PE S	S SE S S S S S S	S S S S S SE S S S	S P S X S S S S S
Neuhausen o.E. (807 m 47°58'/8°54')	S P S P S P X P S P S P S P S P S P X P S X X	S S S S X X X X	S S S S S S S S S	S S S S S S S S S

Table 6/2: Structure-Sonde ascents

S: Ascent with Radio-Sonde
P: Only pilot balloon
X: Omittance
E: Only one theodolite

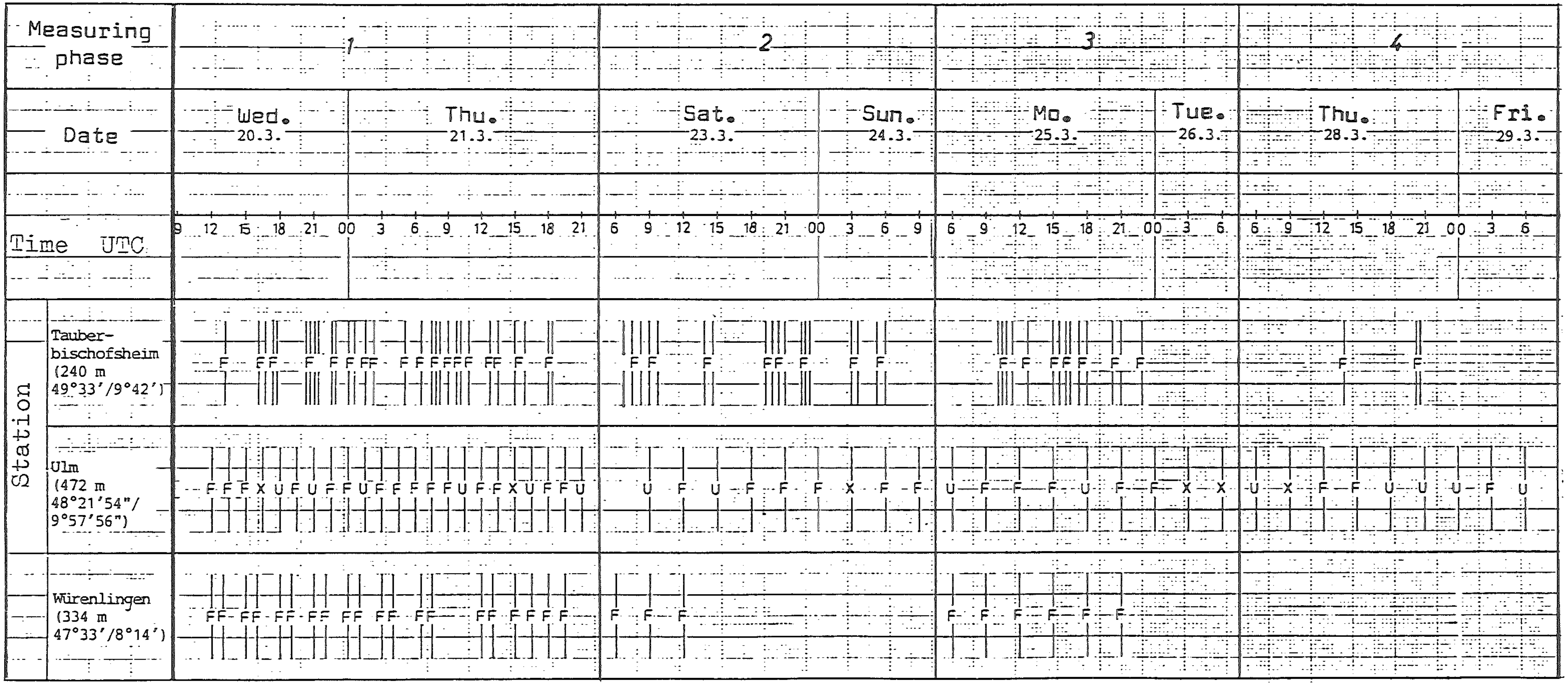


Table 6/3: Tethered balloon ascents

F: Ascent to full height
U: Ascent, but full height not reached
X: No ascent, or ascent not evaluable

SODAR-Location:	Weißenau bei Ravensburg 460 m ü. N.N. 47°46'18" / 9°35'30"
Time of operation:	from 19.3.1985 8:00 UTC to 29.3.1985 12:00 UTC
Measured parameter:	back-scatter amplitude A_W horizontal wind speed WG vertical wind speed w horizontal wind direction WR standard deviation from WR σ_{WR} standard deviation from w σ_w
Averaging time of these parameters:	30 min
Lowest measuring height:	50 m a. g.l
Height intervals:	50 m
Highest measuring height:	1000 m a.g.l

Table 6/4: Information about SODAR

Location	Operator	Height of	WD	WS	temperature	humidity	turbulence	type of data acquisition
Power-station Philippsburg (98 m MSL)	KKP/IMK 49°15'10" 8°26'35"	7	x		x	x		digital, magnetic tape 1 - h values
		40	x	x	x	x		
		70	x		x	x		
		120	x	x	x	x		
KFK-Leopoldshafen (109 m MSL) 49° 5'54" 8°26' 2"	IMK/KFK	20	x	x				digital, disc, magnetic tape 10-min. values
		30	x	x	x	x		
		40	x	x				
		60	x	x			x	
		80	x	x				
		100	x	x	x	x	x	
		130	x	x	x			
		160	x	x	x			
		200	x	x	x	x	x	
		Ground-station	rain, pressure, radiation, temperature, humidity, vectorvane					
Freistett (128 m MSL) 48°40'35" 7°55'10"	Baden-werk/IMK	11	x		x	x		digital, punched tape 30-min. values
		41	x	x	x	x		
		100	x		x	x		
		160	x	x	x	x		
Wyhl (172 m MSL) 48°11'5" 7°38'10"	KWS/IMK	11	x		x	x		digital, punched tape 30-min. values
		40	x	x	x	x		
		101	x		x	x		
		163	x	x	x	x		
Schwör-stadt (288 m MSL) 47°35'10" 7°50'30"	Baden-werk/IMK	10	x		x	x		digital, punched tape 30-min. values
		20	x		x	x		
		40	x	x	x	x		
		80	x		x	x		
		160	x	x				
Obrigheim (270 m MSL) 48°21' 9° 3'	DWD	12		x	x	x		digital, punched tape 30-min. values
		40 5	x	x	x	x		
		101	x	x	x	x		
		160	x	x	x	x		
		Ground-station	rain, pressure, radiation					

Table 6/5: Met towers higher than 100 m in Baden-Württemberg

Station	Location (Gauß-Krüger) co-ordinates RW	HW	Wind direc-tion	Wind-speed	Temp-erature	Dew-point	Global radia-tion	Precipi-tation
Mannheim Nord	3463	5490	+	+	+	+	+	
Mannheim Mitte	3462	5482	+	+	+	+	+	+
Heidelberg	3477	5476			+	+	+	
Karlsruhe West	3453	5430	+	+	+	+	+	
Eggenstein	3457	5438	+	+	+	+	+	
Rastatt	3442	5414	+	+	+	+	+	+
Kehl	3412	5383	+	+	+	+	+	+
Freiburg	3413	5319	+	+	+	+	+	
Weil am Rhein	3397	5273	+	+	+	+	+	+
S-Bad Canstatt	3517	5408	+	+	+	+		
S-Zuffenhausen	3513	5410	+	+	+	+		
S-Hafen	3520	5402	+	+	+	+	+	
Esslingen	3524	5399	+	+	+	+	+	+
Plochingen	3530	5397	+	+	+	+	+	+
Ludwigsburg	3518	5418	+	+	+	+	+	+
Heilbronn	3516	5447	+	+	+	+	+	
Göppingen	3550	5396	+	+	+	+	+	+
Aalen-Wasseralf.	3580	5413	+	+	+	+	+	+
Reutlingen	3515	5372	+	+	+	+	+	+
Staufen			+	+	+	+	+	+

Table 6/6: LfU-stations which register meteorological parameters

Tetroon	Transponder	Date	Launching Site	Launching Time UTC	Average values $\bar{H}$ (m)	Average values $\bar{u}$ (m/s)	Average values $\overline{DD}$ (Grad)	tracked to R (km)	tracked to t (h:min)
TU8501	T16	20.3.	Weingarten 114 m MSL 49°2'54" 8°31'35"	12:05	200	1,9	214	5	0:53
TU8502	T12	21.3.	Klippen-eck 960 m MSL 48°6'20" 8°45'30"	10:27	150	4,4	67	41	2:48
TU8503	T25	21.3		14:12	Transponder not in operation				
TU8504	-	23.3	Minfeld 161 m MSL 49°5'3" 8°8'30"	8:26	1100	12,9	231	51	0:29
TU8505	-	23.3.		11:00	700	10,4	234	71	1:55
TU8506	-	23.3.		13:03	750	8,9	227	98	3:07
TU8507	-	23.3.		16:43	450	9,5	209	84	2:27
TU8508	-	25.3.	Minfeld 161 m MSL 49°5'3" 8°8'30"	7:51	400→1500	11,0	239	111	2:51
TU8509	-	25.3.		10:49	600	6,9	192	111	4:53
TU8510	-	25.3.		16:05	550	6,8	209	87	3:40
TU8511	-	28.3.	Katzen-buckel 580 m MSL 49°28'12" 9°2'30"	11:00	800	9,0	298	35	1:08
TU8512	-	28.3.		13:03	250	6,7	275	7	0:19
TU8513	-	28.3.		14:17	350	8,1	280	14	0:30

Table 7/1: Tetroon-flights

Date	23.3.1985	25.3.1985	28.3.1985
Emission site	Heizkraftwerk Karlsruhe (HKW)	HKW	Katzenbuckel
Emission height	140 m	140 m	10 m
Rate of emission (g/s)	28,1	28,5	27,1
Time of emission in UTC	10:00 - 14:55	9:30 - 14:20	11:00 - 15:07
average distance of circular arc from the source in km			
1. Arc	12	12	13
2. Arc	33	33	24
3. Arc	60	60	58
Collecting time (UTC)	12:00 - 15:00	12:00 - 14:30	13:30 - 15:30
Amount of collection periods	6	5	4
Amount of collection sites			
1. Arc	16	16	16
2. Arc	20	20	20
3. Arc	24	24	24

Table 7/2: Information about tracer-experiments

Satellite	Date	Time (UTC)
NOAA-9	20.3.	3.08
NOAA-9		6.58
NOAA-9		12.58
NOAA-9	21.3.	2.58
NOAA-9	22.3.	2.36
NOAA-6	25.3.	6.37
NOAA-9	26.3.	2.04
NOAA-9		6.15
NOAA-9	27.3.	1.53
NOAA-9	29.3.	8.23
NOAA-9		13.02

Table 7/3: NOAA-Satellite pictures during TULLA

Station	Location co-ordinates	
	Rechtswert	Hochwert
Karlsruhe-Mitte	3457	5431
Karlsruhe-West	3453	5430
Karlsruhe-Neureut	3454	5434
Eggenstein	3457	5438
Mannheim-Mitte	3462	5482
Mannheim-Nord	3463	5490
Mannheim-Süd	3466	5477
Heidelberg	3477	5476
Stuttgart-Zuffenhausen	3513	5410
Stuttgart-Mitte	3512	5404
Stuttgart BC	3517	5408
Stuttgart Hafen	3520	5402
Ludwigsburg	3518	5418
Esslingen	3524	5399
Plochingen	3530	5397
Ulm	3573	5363
Heilbronn	3516	5447
Göppingen	3550	5396
Aalen	3580	5413
Reutlingen	3515	5372
Rastatt	3442	5414
Kehl	3412	5383
Freiburg	3413	5319
Weil am Rhein	3397	5273
Münstertal, Kälbelesscheuer	3408	5297
Rudersberg, Edelmannshof	3542	5416

Table 8/1: Position of the stations within the air-measuring net in Baden-Württemberg

Measuring site – Name of station / components	MA-Nord	MA-Mitte	MA-Süd	Heidelberg	KA-Mitte	KA-West	KA-Neureut	KA-Eggenstein	Rastatt	Kehl	Freiburg	Weil am Rhein	S-Mitte	S-Bad Cannstatt	S-Zuffenhausen	S-Hafen	Esslingen	Plochingen	Ludwigsburg	Heilbronn	Göppingen	Aalen-Wasseralfingen	Ulm	Reutlingen
dust contents	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
carbon monoxide	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
carbon dioxide	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
sum of carbohydrate without methane	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
nitrogen monoxide	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
nitrogen dioxide	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
sulfur dioxide	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
ozone	x	x	x		x	x	x	x	x		x			x	x	x				x			x	
wind direction	x	x				x		x	x	x	x	x		x	x	x	x	x	x	x	x	x		x
wind speed	x	x				x		x	x	x	x	x		x	x	x	x	x	x	x	x	x		x
air temperature	x	x		x		x		x	x	x	x	x		x	x	x	x	x	x	x	x	x		x
dew point	x	x		x		x		x	x	x	x	x		x	x	x	x	x	x	x	x	x		x
global radiation	x	x		x		x		x	x	x	x	x		x			x	x	x	x	x	x		x
amount of precipitation		x							x	x		x					x	x	x		x	x		x
noise level		x			x	x	x	x					x	x	x	x								
γ/β – level										x	x													

Table 8/2: Measuring components of the LfU stations in Baden-Württemberg

Measuring-sites	Co-ordination Gauß-Krüger RW	HW	Operator	Parameter	Measuring-dates	Responsible partner
Speyer, Feuerwehr	3459	5463	Landesamt f. Umweltschutz Rheinland/Pfalz	SO_2, NO, NO_2, O_3	15.3. - 29.3.1985	Dr. Bockolt
Ludwigshafen-Oppau	3456	5486	"	SO_2, NO, NO_2	" "	"
" Mitte	3459	5483	"	CO, CNHM	" "	"
" Mundenheim	3458	5480	"	"	" "	"
Waldenbuch	3457	5366	Institut für Verfahrenstechnik der Universität Stuttgart	SO_2, NO, NO_2, O_3	19.3. - 29.3.1985	Dr. Baumbach
Freudenstadt	3510	5386	"	"	" "	"
Hohengeren 3	3533	5402	Neckarwerke	SO_2, NO, NO_2	18.3. - 29.3.1985	Dr. Necker
Plochingen	3531	5397	"	O_3	25.3. - 26.3.1985 28.3. - 29.3.1985	"
Schorndorf	3537	5408	Energieversorgung Schwaben	"	11.3. - 29.3.1985	Dr. Beising
Wilhelmsfeld	3480	5482	Landesanstalt f. Umweltschutz-BW	"	1.3. - 31.3.1985	Dr. Obländer
Ravensburg	3555	5294	"	"	" "	"
Freistett	3421	5394	Badenwerk Karlsruhe	SO_2, NO, NO_2	18.3. - 29.3.1985	Dr. Schlövogt
Schwörstadt	3413	5273	"	"	" "	"
Hornisgrinde	3441	5386	"	"	" "	"
Schauinsland (1250 m)	?	?	UBA-Pilotstation	SO_2, NO_2, O_3	19.3. - 29.3.1985	Dr. Graul
" (952 m)	?	?		SO_4, CO_2		
				SO_2, O_3	" "	
Werksgelände der BASF-Ludwigshafen	3459	5486[1)]	BASF	an 7 Stationen SO_2	" "	Dr. Mutz
Basel	?	?	Amt für Lufthygiene Basel-Land	an 6 Stationen SO_2	" "	Dr. Mona
Basel, St. Margarethen	?	?	Bundesamt für Umweltschutz	NO, NO_2, O_3	" "	Dr. Gehrig
Würzburg	?	?	Bayr. Landesamt für Umweltschutz	SO_2, CO	" "	Dr. Hoft
Neu-Ulm	?	?	"	"	" "	"
Lindau	?	?	"	"	" "	"

Table 8/3: Further measuring stations

1) The exact co-ordinates of the seven stations can be obtained from the TULLA-data-bank

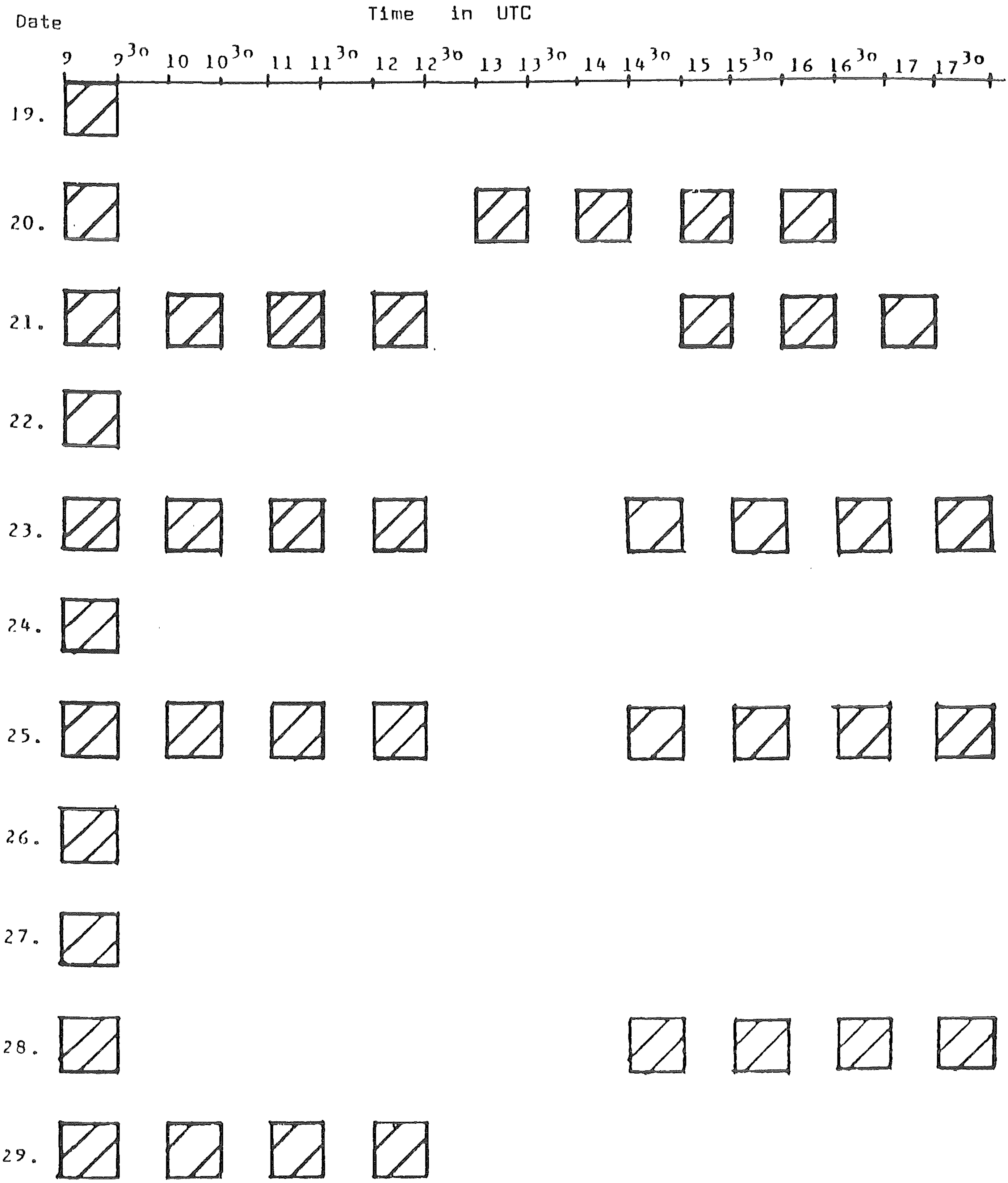


Table 8/4: Measurement intervals of the TULLA ground measuring stations 1-10
stations 1-10

Particle collection

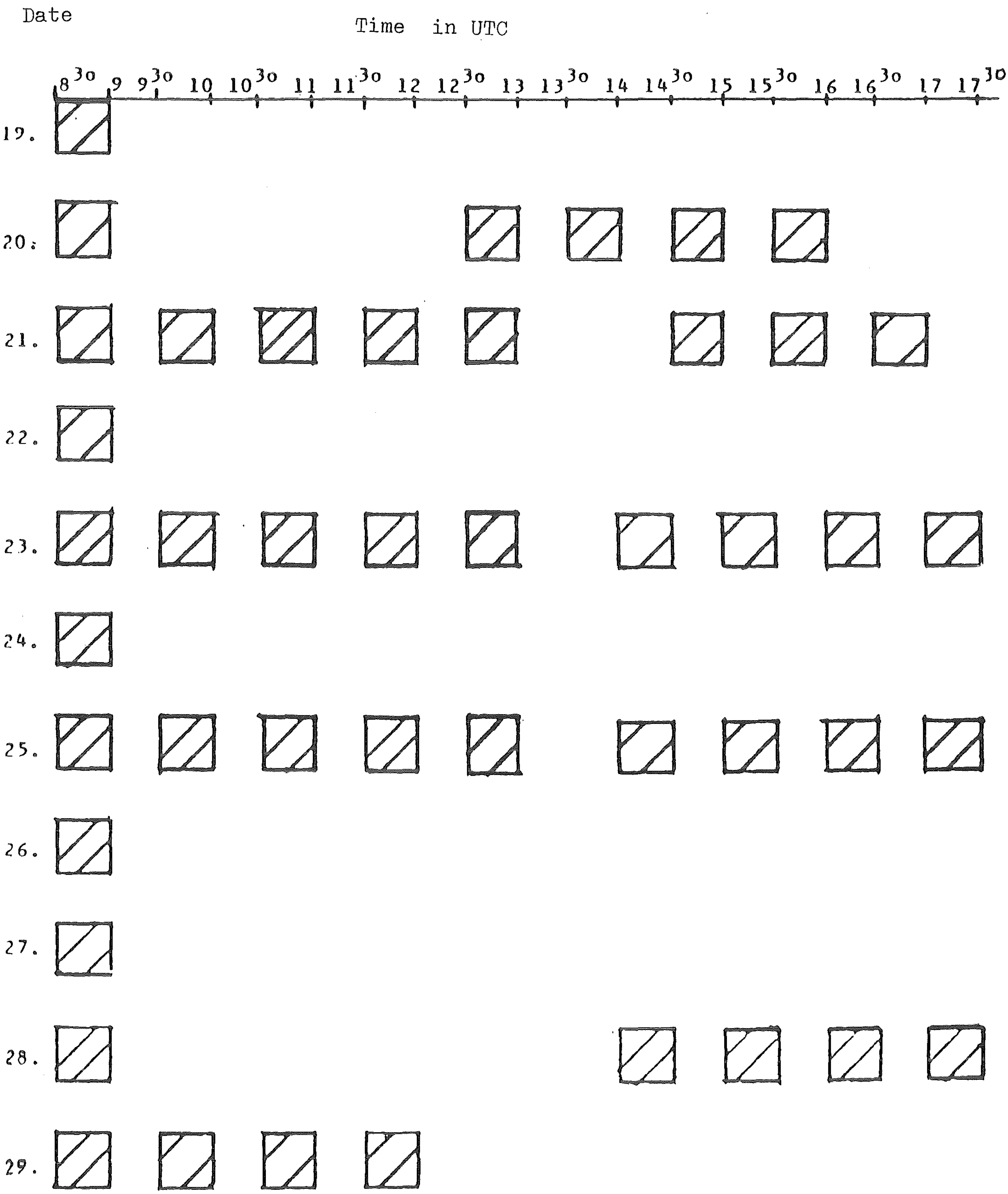


Table 8/5: Measurement intervals of the TULLA ground measuring stations 1-10
SO_2 Enrichment

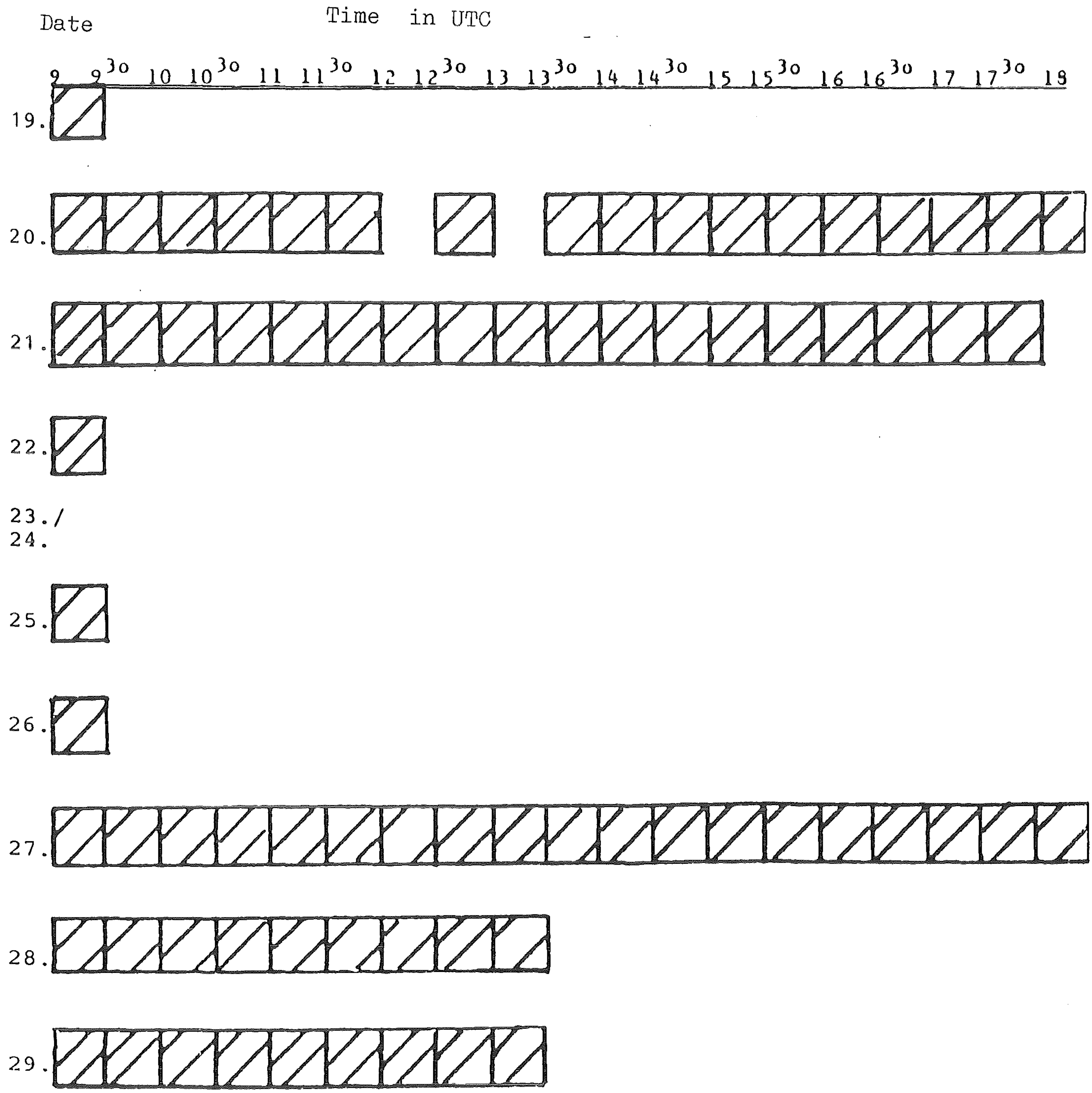


Table 8/6: Measurement intervals of the TULLA-ground
measuring station "Schauinsland"
Particle collection

Date	Measuring span UTC	Location	Number of impactors
20.3.	10:00 ÷ 17:00	Kälbelescheuer (2 Stationen)	2 x 7
	10:00 ÷ 17:00	Untergrombach (2 Stationen)	2 x 7
	10:00 ÷ 17:00	Edelmannshof	9
	10:00 ÷ 17:00	Dürrenmettstetten	12
	10:00 ÷ 17:00	Hohenheim	8
21.3	8:00 ÷ 17:00	Kälbelescheuer (2 Stationen)	2 x 10
	9:00 ÷ 18:00	Untergrombach (2 Stationen)	2 x 10
	9:00 ÷ 17:00	Edelmannshof	14
	8:00 ÷ 17:00	Dürrenmettstetten	20
	10:00 ÷ 17:00	Hohenheim	8
28.3.	10:00 ÷ 17:00	Käbelescheuer (2 Stationen)	2 x 7
	10:00 ÷ 17:00	Untergrombach (2 Stationen)	2 x 7
	10:00 ÷ 17:00	Edelmannshof	9
	10:00 ÷ 17:00	Dürrenmettstetten	12
	10:00 ÷ 17:00	Hohenheim	8

Table 8/7: Ground - based mini-impactors

Measuring value \ Time span	19.3.85 21.50 UTC – 20.3.85 9.37 UTC	20.3.85 9.37 UTC – 20.3.85 11.20 UTC	20.3.85 11.20 UTC – 21.3.85 19.50 UTC	21.7.85 19.50 UTC – 22.3.85 22.13 UTC	22.3.85 22.13 UTC – 23.3.85 1.20 UTC	23.3.85 1.30 UTC – 23.3.85 2.00 UTC	23.3.85 2.00 UTC – 23.3.85 11.30 UTC
average horiz. wind speed in 5 heights at the same time							
average air temp. in 3 heights simultaneously	10 Minuten Mittelwerte	keine Messungen	10 Minuten Mittelwerte	keine Messungen	1 Minute Mittelwerte	2,5 Minuten Mittelwerte	keine Messungen
SO_2 concentration in 3 heights consecutively							
Global radiation (Dirnhirn) approx. 8,5 m high							
Air humidity air pressure, temp. continuously with Meteorograph	kontinuierlich						
continual wind direction	kontinuierlich						

Measuring value \ Time span	23.3.85 11.30 UTC – 24.3.85 8.08 UTC	23.3.85 8.09 UTC – 24.3.85 13.26 UTC	24.3.85 13.26 UTC – 24.3.85 14.22 UTC	24.3.85 14.22 UTC – 24.3.85 14.45 UTC	24.3.85 14.45 UTC – 25.3.85 9.11 UTC	25.3.85 9.15 UTC – 25.3.85 9.35 UTC	25.3.85 9.35 UTC – 25.3.85 11.10 UTC
average horiz. wind speed in 5 heights at the same time							
average air temp. in 3 heights simultaneously	2,5 Minuten Mittelwerte	2 Minuten Mittelwerte	keine Messung	3 Minuten Mittelwerte	keine Messung	2 Minuten Mittelwerte	keine Messung
SO_2 concentration in 3 heights consecutively							
Global radiation (Dirnhirn) approx. 8,5 m high							
Air humidity air pressure, temp. continuously with Meteorograph	kontinuierlich						
continual wind direction	kontinuierlich						

Table 8/8: Deposition measurements in Linkenheim-measuring team KfK

Continuation Table 8/8

Time span / Measuring value	25.3.85 11.10 UTC 25.3.85 11.31 UTC	25.3.85 11.31 UTC 25.3.85 13.06 UTC	25.3.85 13.06 UTC 25.3.85 14.14 UTC	25.3.85 14.14 UTC 26.3.85 12.22 UTC	26.3.85 12.22 UTC 26.3.85 14.08 UTC	26.3.85 14.08 UTC 26.3.85 19.41 UTC	26.3.85 19.41 UTC 26.3.85 20.32 UTC
average horiz. wind speed in 5 heights at the same time							
average air temp. in 3 heights simultaneously	1 Minute Mittelwerte	2 Minuten Mittelwerte		2 Minuten Mittelwerte		2 Minuten Mittelwerte	
SO_2 concentration in 3 heights consecutively			keine Messung		keine Messung		keine Messung
Global radiation (Dirnhirn) approx. 8,5 m high							
Air humidity air pressure, temp. continuously with Meteorograph	kontinuierlich						
continual wind direction	kontinuierlich						

Time span / Measuring value	26.3.85 20.32 UTC 26.3.85 22.39 UTC	26.3.85 22.39 UTC 26.3.85 23.48 UTC	26.3.85 23.48 UTC 27.3.85 1.30 UTC	27.3.85/ 1.30 UTC 27.3.85 2.29 UTC	27.3.85 2.30 UTC 27.3.85 3.09 UTC	27.3.85 3,15 UTC 29.3.85 0.29 UTC	
average horiz. wind speed in 5 heights at the same time							
average air temp. in 3 heights simultaneously	2 Minuten Mittelwerte		2 Minuten Mittelwerte	1,5 Minuten Mittelwerte	1 Minute Mittelwerte	1,5 Minuten Mittelwerte	
SO_2 concentration in 3 heights consecutively		keine Messungen					
Global radiation (Dirnhirn) approx. 8,5 m high							
Air humidity air pressure temp. continuously with Meteorograph	kontinuierlich						
continual wind direction	kontinuierlich						

Date	Time in UTC Start	End	Driving distance	Measured quantity	Operator
20.3.1985	9:20	13:10	Achern - Weil am Rhein - Achern	SO_2	GFS-Ispra
	11:35	16:20	4 x Viernheimer Dreieck - Walldorfer Kreuz - Frankenthaler Kreuz - Viernheimer Dreieck	SO_2 und NO_2	UBA-Frankfurt
	10:08	12:10	Appenweier - Walldorfer Kreuz - Hockenheimer Dreieck-Viernheimer Dreieck - Frankenthaler Kreuz - Hockenheimer Dreieck	SO_2 und NO_2	Inst. für Hygiene und Epidemiologie (I.H.E.) Brüssel
	12:20	14:05	Hockenheimer Dreieck - Frankenthaler Kreuz - Viernheimer Dreieck - Appenweier		
21.3.1985	9:45	15:00	Appenweier - Mannheim - Appenweier	SO_2	GFS-Ispra
	9:35	12:15	2 x Fahrtstrecke wie am 20.3.1985	SO_2 und NO_2	UBA-Frankfurt
	13:00	15:45	2 x Fahrtstrecke wie am 20.3.1985		
	10:00	11:15	Achern - Weil am Rhein	SO_2 und NO_2	I.H.E. - Brüssel
	13:25	14:40	Weil am Rhein - Achern		
23.3.1985	9:00	14:20	Achern - Lörrach - Achern	SO_2	GFS-Ispra
	keine Meßfahrt wegen technischer Schwierigkeiten				UBA-Frankfurt
	9:31	12:01	Appenweier - Walldorfer Kreuz - Hockenheimer Dreieck - Viernheimer Dreieck - Frankenthaler Kreuz - Karlsruhe-Durlach	SO_2 und NO_2	I.H.E. - Brüssel
	12:40	15:20	Karlsruhe-Durlach - Walldorfer Kreuz - Hockenheimer Dreieck - Frankenthaler Kreuz - Viernheimer Dreieck - Appenweier		
25.3.1985	9:00	15:00	Achern - Mannheim - Achern	SO_2	GFS-Ispra
	11:40	15:00	2 x Fahrtstrecke wie am 20.3.1985	SO_2 und NO_2	UBA-Frankfurt
	8:29	10:05	Bühl - Weil am Rhein	SO_2 und NO_2	I.H.E. - Brüssel
	13:00	14:20	Weil am Rhein		
27.3.1985	9:03	10:16	Achern - Weil am Rhein	SO_2 und NO_2	I. H.E. - Brüssel
	10:36	12:45	Weil am Rhein - Karlsruhe-Rheinhafen - Landau		
	13:04	13:41	Landau - Karlsruhe - Pforzheim-West		

Table 8/9: Schedule of the COSPEC-measuring vans

Continuation Table 8/9

Date	Time in UTC Start	End	driving distance	Measured quantity	Operator
28.3.1985	9:00	16:30	Achern - Baden-Baden - Hagenau - Strasbourg - Mulhouse - Neuenburg - Achern	SO_2	GFS-Ispra
	14:00	15:30	1 x Fahrtstrecke wie am 20.3.1985	SO_2	UBA-Frankfurt
	9:26	15:39	Appenweier - Walldorfer Kreuz - Hockenheimer Dreieck - Frankenthaler Kreuz - Viernheimer Dreieck - Weil am Rhein - Appenweier	SO_2 und NO_2	I.H.E. - Brüssel
29.3.1985	8:50	11:30	Achern - Basel - Achern	SO_2	GFS-Ispra
	9:15	12:00	2 x Fahrtstrecke wie am 20.3.1985	SO_2 und NO_2	UBA-Frankfurt
	9:55	11:25	Appenweier - Walldorfer Kreuz - Hockenheimer Dreieck - Viernheimer Dreieck - Frankenthaler Kreuz	SO_2 und NO_2	I.H.E. - Brüssel

Institution those responsible	SO_2				NO_x				O_3			
	device	LDL ppbv	Resp. 90% sec	Flow l/min	device	LDL ppbv	Resp. 90% sec	Flow l/min	device	LDL ppbv	Resp. 90% sec	Flow l/min
C E A Carbonelle	Meloy SA 285 FPD	1 own	30 calib.	12	Environment SA Chem. Lum.	5 own	40 calib.	12	--	-- --	--	--
C E R L Marsh	Meloy SA 285 FPD	2 own	75 calib.	0.2	Monitor Labs Chem. Lum.	2 own	120 calib.	0.5	Bendix 8002 Chem. Lum.	1 own	22 calib.	1
D F V L R Paffrath	Meloy SA 285 FDP	0.5 own	95/130 calib.	0.2	Monitor Labs Chem. Lum.	2 own	95/20 calib.	0.25	CSI 2000 Chem. Lum.	2 own	95/18 calib.	0.7
Geosens Spoelstra	Thermo.Electr Fluorescence	3 no	1 calib.	20/0.5	Thermo Electr Chem. Lum.	4 no	1 calib.	1	Bendix 8002 Chem. Lum.	3 own	1 calib.	1
N I L U Berg	Environment SA Fluorescence	30/4 no	5/120 calib.	2	Environment SA Chem. Lum.	30/2 no	.4/50 calib.	1.2	CSI 2000 Chem. Lum.	4 no	15 calib.	0.7
Th Darmstadt Bächmann	Monitor Labs Fluorscence	5/1	120/ 210	0.5	Environment SA Chem. Lum.	3 no	30 calib.	1.25	Dasibi 1008 PC UV-Absorp.	3 own	99/50 calib.	2
Uni Ffm Jaeschke	Monitor Labs Fluorescence	5/1 own	120/ 210 calib.	0.5	Monitor Labs Chem. Lum.	5/2 own	7/120 calib.	1	Bendix 8002 Chem. Lum.	5 own	10 calib.	0.8

Table 9/1: Summary of the instruments used in the aircraft

Route	Checkpoint	Geographical				co-ordinates			
L1	1:	49	33	20	N	08	18	50	E
	2:	49	21	50	N	08	22	10	E
	3:	49	01	40	N	08	11	45	E
	4:	48	46	42	N	08	04	02	E
	5:	48	28	10	N	07	54	50	E
	6:	47	09	40	N	07	45	35	E
	7:	47	48	30	N	07	35	05	E
	8:	47	38	00	N	07	30	00	E
L2	9:	49	36	40	N	09	41	20	E
	10:	49	24	50	N	09	31	00	E
	11:	49	09	25	N	09	17	55	E
	12:	48	59	15	N	09	09	10	E
	13:	48	47	20	N	08	59	10	E
	14:	48	37	00	N	08	50	30	E
	15:	48	22	57	N	08	38	45	E
	16:	48	08	00	N	08	34	20	E
	17:	47	55	00	N	08	30	30	E
	18:	47	41	30	N	08	26	18	E
L3	19:	49	34	45	N	10	12	10	E
	20:	49	28	40	N	10	12	40	E
	21:	49	08	38	N	10	14	22	E
	22:	48	58	40	N	10	15	05	E
	23:	48	48	40	N	10	15	55	E
	24:	48	36	05	N	10	17	00	E
	25:	48	26	00	N	10	17	47	E
	26:	48	10	05	N	10	19	00	E
	27:	47	54	50	N	10	20	10	E
	28:	47	44	47	N	10	21	04	E

Table 9/2: Geographical co-ordinates of the checkpoints of the North-South routes L1 to L3

Route	Checkpoint	Co-ordinates							
T1A	1:	49	33	20	N	08	18	50	E
	29:	49	17	30	N	08	26	20	E
	30:	48	59	33	N	08	35	06	E
	31:	49	09	20	N	08	52	10	E
	32:	49	18	30	N	09	08	55	E
	33:	49	26	00	N	09	22	10	E
	9:	49	36	40	N	09	41	20	E
	19:	49	34	45	N	10	12	10	E
T1B	2:	49	21	50	N	08	22	10	E
	35:	49	20	12	N	08	44	00	E
	36:	49	22	20	N	09	05	20	E
	10:	49	24	50	N	09	31	00	E
	37:	49	27	00	N	09	55	25	E
	20:	49	28	40	N	10	12	40	E
T1C	3:	49	01	40	N	08	11	45	E
	30:	48	59	33	N	08	35	06	E
	38:	48	57	30	N	08	55	30	E
	39:	48	54	51	N	09	20	28	E
	40:	48	52	10	N	09	45	50	E
	23:	48	48	40	N	10	15	55	E
T2	5:	48	28	10	N	07	54	50	E
	41:	48	26	20	N	08	10	25	E
	42:	48	24	25	N	08	26	50	E
	15:	48	22	57	N	08	38	45	E
	43:	48	20	10	N	09	01	50	E
	44:	48	18	30	N	09	14	55	E
	45:	48	16	25	N	09	31	05	E
	46:	48	13	50	N	09	51	00	E
	47:	48	11	50	N	10	07	25	E
	26:	48	10	05	N	10	19	00	E
T3	8:	47	38	00	N	07	30	00	E
	48:	47	39	00	N	07	44	40	E
	49:	47	40	00	N	07	59	30	E
	50:	47	40	50	N	08	14	05	E
	18:	47	41	30	N	08	26	18	E
	51:	47	42	05	N	08	41	15	E
	52:	47	42	50	N	09	05	00	E
	53:	47	43	20	N	09	23	25	E
	54:	47	43	55	N	09	42	10	E
	55:	47	44	25	N	10	03	55	E
	28:	47	44	47	N	10	21	04	E

Table 9/3: Geographical co-ordinates of the checkpoints of the West-East routes T1A to T3

Checkpoint	Co-ordinates							
1:	49	33	20	N	08	18	50	E
2:	49	21	50	N	08	22	10	E
3:	49	01	40	N	08	11	45	E
4:	48	46	42	N	08	04	02	E
5:	48	28	10	N	07	54	50	E
6:	48	09	40	N	07	45	35	E
7:	47	48	30	N	07	35	05	E
8:	47	38	00	N	07	30	00	E
9:	49	36	40	N	09	41	20	E
10:	49	24	50	N	09	31	00	E
11:	49	09	25	N	09	17	55	E
12:	48	59	15	N	09	09	10	E
13:	48	47	20	N	08	59	10	E
14:	48	37	00	N	08	50	30	E
15:	48	22	57	N	08	38	45	E
16:	48	08	00	N	08	34	20	E
17:	47	55	00	N	08	30	30	E
18:	47	41	30	N	08	26	18	E
19:	49	34	45	N	10	12	10	E
20:	49	28	40	N	10	12	40	E
21:	49	08	38	N	10	14	22	E
22:	48	58	40	N	10	15	05	E
23:	48	48	40	N	10	15	55	E
24:	48	36	05	N	10	17	00	E
25:	48	26	00	N	10	17	47	E
26:	48	10	05	N	10	19	00	E
27:	47	54	50	N	10	20	10	E
28:	47	44	47	N	10	21	04	E
29:	49	17	30	N	08	26	20	E
30:	48	59	33	N	08	35	06	E
31:	49	09	20	N	08	52	10	E
32:	49	18	30	N	09	08	55	E
33:	49	26	00	N	09	22	10	E
34:	not available							
35:	49	20	12	N	08	44	00	E
36:	49	22	20	N	09	05	20	E
37:	49	27	00	N	09	55	25	E
38:	48	57	30	N	08	55	30	E
39:	48	54	51	N	09	20	28	E
40:	48	52	10	N	09	45	50	E
41:	48	26	20	N	08	10	25	E
42:	48	24	25	N	08	26	50	E
43:	48	20	10	N	09	01	50	E
44:	48	18	30	N	09	14	55	E
45:	48	16	25	N	09	31	05	E
46:	48	13	50	N	09	51	00	E
47:	48	11	50	N	10	07	25	E
48:	47	39	00	N	07	44	40	E
49:	47	40	00	N	07	59	30	E
50:	47	40	50	N	08	14	05	E
51:	47	42	05	N	08	41	15	E
52:	47	42	50	N	09	05	00	E
53:	47	43	20	N	09	23	25	E
54:	47	43	55	N	09	42	10	E
55:	47	44	25	N	10	03	55	E

Table 9/4: List of the arranged geographical co-ordinates of all checkpoints

Wind from Numbers in degree	Pattern
210 to 270	A
270 to 330	B
330 to 45	C
45 to 135	B
135 to 210	C

Table 9/5: Flight-pattern and wind direction

Aircraft	Wed. 20.3.1985 p.m.	Thu. 21.3.1985 a.m.	Thu. 21.3.1985 p.m.	Sat. 23.3.1985 a.m.	Sat. 23.3.1985 p.m.	Mon. 25.3.1985 a.m.	Mon. 25.3.1985 p.m.	Thu. 28.3.1985 p.m.	Fri. 29.3.1985 a.m.
TULLA 1R	+	+	+	+	+	+	+	abgebrochen	+
TULLA 2R	+	+	+	+	+	+	+		ausgefallen
TULLA 3R	+	+	+	+	+	+	+		als TULLA 6B geflogen
TULLA 4R	+	+	+	+	+	+	+		+
TULLA 5B	+	ausgef.	+	+	ausgef.	+	+		+
TULLA 6B	ausgef.	ni.gestart.	+	+	+	+	+		+
TULLA 7B	+	ni.gestart.	+	+	+	+	+		
PATTERN	C	C		A	A*)	A		B	A

Aircraft	Wed. 20.3.1985	Thu. 21.3.1985	Sat. 23.3.1985	Mon. 25.3.1985	Thu. 28.3.1985	Fri. 29.3.1985
TULLA 1R	NILU	U.DARMSTADT	U.DARMSTADT	U.DARMSTADT	U.DARMSTADT	U.DARMSTADT
TULLA 2R	U.DARMSTADT	NILU	NILU	NILU	NILU	-
TULLA 3R	CEA	CEA	CEA	CEA	CEA	-
TULLA 4R	GEOSENS	GEOSENS	GEOSENS	GEOSENS	GEOSENS	GEOSENS
TULLA 5B	CERL	CERL	CERL	CERL	CERL	DFVLR
TULLA 6B	DFVLR	DFVLR	DFVLR	DFVLR	DFVLR	CEA
TULLA 7B	UN.FRA.	U.FRA.	U.FRA.	U.FRA.	U.FRA.	U.FRANKF.

*) red formation could not fly the complete pattern A due to clouds, southern border from checkpoint 26 directly to checkpoint 5

Table 9/6: Flights performed and arrangement of the aircraft

Aircraft	Date	Start UTC	Landing UTC	Flight height (relative to Figs. 9/5 to 9/9)
TULLA 1R	20-3-1985	13:04	16:19	+ 1500 ft
TULLA 2R		13:05	16:20	+ 1000 ft
TULLA 3R		13:05	16:14	+ 500 ft
TULLA 4R		13:05	16:13	+ 0 ft
TULLA 5B		12:58	15:55	+ 1500 ft
TULLA 6B		ausgef.	ausgef.	+ 1000 ft
TULLA 7B		13:00	15:49	+ 0 ft
TULLA 1R	21.3.1985	08:31	11:29	+ 1800 ft
TULLA 2R		08:31	11:28	+ 1000 ft
TULLA 3R		08:31	11:27	+ 500 ft
TULLA 4R		08:32	11:26	+ 0 ft
TULLA 5B hatte Startprobleme, Formation Blau daher nicht gestartet		-	-	+ 1000 ft
		-	-	+ 500 ft
		-	-	+ 0ft
TULLA 1R		14:02	17:02	+ 1800 ft
TULLA 2R		14:02	17:01	+ 1000 ft
TULLA 3R		14:03	17:01	+ 500 ft
TULLA 4R		14:03	17:00	+ 0 ft
TULLA 5B		13:48	16:42	+ 1000 ft
TULLA 6B		13:56	16:41	+ 500 ft
TULLA 7B		13:57	16:40	+ 0 ft
TULLA 1R	23.3.1985	07:56	11:49	+ 900 ft
TULLA 2R		07:56	11:47	+ 600 ft
TULLA 3R		07:56	11:44	+ 300 ft
TULLA 4R		07:56	11:44	+ 0 ft
TULLA 5B		07:56	11:31	+ 600 ft
TULLA 6B		07:57	11:30	+ 300 ft
TULLA 7B		08:02	11:29	+ 0 ft
TULLA 1R		13:42	16:43	+ 900 ft
TULLA 2R		13:42	16:41	+ 600 ft
TULLA 3R		13:43	16:41	+ 300 ft
TULLA 4R		13:43	16:40	+ 0 ft

Table 9/7: Time schedule of flights

Continuation Table 9/7

Aircraft	Date	Start UTC	Landing UTC	Flight height (relative to Figs. 9/5 to 9/9)
TULLA 5B	23.3.1985	ausgef.	ausgef.	ausgef.
TULLA 6B		13:47	17:12	+ 300 ft
TULLA 7B		13:47	17:11	+ 0 ft
TULLA 1R	25.3.1985	07:53	11:36	+ 900 ft
TULLA 2R		07:53	11:36	+ 600 ft
TULLA 3R		07:54	11:35	+ 300 ft
TULLA 4R		07:54	11:33	+ 0 ft
TULLA 5B		08:23	11:48	+ 600 ft
TULLA 6B		08:15	11:46	+ 300 ft
TULLA 7B		08:15	11:48	+ 0 ft
TULLA 1R		13:31	17:24	+ 900 ft
TULLA 2R		13:31	17:21	+ 600 ft
TULLA 3R		13:32	17:20	+ 300 ft
TULLA 4R		13:33	17:20	+ 0 ft
TULLA 5B		13:54	17:35	+ 600 ft
TULLA 6B		13:54	17:22	+ 300 ft
TULLA 7B		14:00	17:23	+ 0 ft
TULLA 1R	29.3.1985	08:59	12:47	+ 300 ft
TULLA 4R		08:59	12:45	+ 0 ft
TULLA 5B		07:52	11:23	+ 600 ft
TULLA 6B		07:52	11:23	+ 300 ft
TULLA 7B		07:53	11:12 (in Egelsbach)	+ 0 ft

	Checkpoint Begin	End	approx. flight duration (from: TULLA-operation plan)
Red-formation (TULLA 1 - 4)	3	1	16' 30"
	1	30	17' 30"
	30	9	28' 30"
	9	21	23'
	21	25	21' 15"
	25	28	20' 45"
	28	53	19' 30"
	53	18	19' 15"
	18	8	19'
	8	6	16' 30"
	6	3	27' 15"
Blue-formation (TULLA 5 - 7)	3	6	27' 15"
	6	8	16' 30"
	8	18	19'
	18	15	21' 15"
	15	12	20' 30"
	12	9	25'
	9	30	28' 30"
	30	1	17' 30"
	1	3	16' 30"

Table 9/8: Information as to the particle-bound measurements
Flight-pattern A

	Checkpoint Begin	End	approx. flight duration (from: TULLA-operation plan)
Red-formation (TULLA 1 - 4)	3	5	17' 30"
	5	8	26' 15"
	8	18	19'
	18	53	19' 15"
	53	28	19' 30"
	28	23	31' 15"
	23	39	18' 30"
	39	3	22' 45"
Blue-formation (TULLA 5 - 7)	3	35	17' 45"
	35	10	15' 30"
	10	21	23' 30"
	21	26	29' 15"
	26	43	29' 30"
	43	5	21' 45"
	5	3	17' 30"

Table 9/9: Information as to the particle-bound measurements
Flight-pattern C

Date	Measuring time period	Number of impactors within the plane Univ. Darmstadt	Geosens
2o.3.	p.m.	12	12
21.3.	a.m.	12	12
	p.m.	12	12
28.3.	p.m.	1	6
29.3.	a.m.	12	12

Table 9/10: Airborne mini-impactors

Date	Start UTC	Landing UTC	flight pattern
21.3.	13:20	18:03	C complete
23.3.	12:54	18:30	A complete
25.3.	12:50	15:22	A only red flight route flight above Kempten broken off due to power failure
28.3.	13:04	19:12	B complete

Table 9/11: Time schedule of the aircraft HS 125

Checkpoint	Altitude
1 - 5	Steigflug bis ca. 3000 m NN
5 - 6	Sinkflug, Spirale Uber Rheinfelden
6 - 18	W-E-Traverse 150 ± 50 m Grund
18 - 20	Steigflug bis ca. 3000 m NN
20 - 21	Sinkspirale Uber Romanshorn
21 - 29	E-W-Traverse 250 ± 50 m Grund

Table 9/12: Vertical profile of the flight route of the motor-glider ASK-16

Flight-No.	Date	Take-off UTC	Touch-down UTC		max. altitude			
				Basel (mNN)	Pkte. 3/4/5 (UTC)		Friedrichs-hafen (mNN)	Pkt. 20 (UTC)
1 *	20.3.	12.51	16.30	3000	13.32		2000	15.21
2	21.3.	12.23	16.12	2500	12.53		3000	14.48
3	23.3.	13.26	16.41	2000	13.43		2250	15.16
4	25.3.	08.25	11.48	3000	09.00		3000	10.40
5	25.3.	13.31	17.06	3000	13.59		3150	15.44
6	28.3.	12.39	16.22	2500	13.03		2500	14.42
7	29.3.	08.41	12.10	3000	09.11		3000	10.50

* Ozone only for points 1 to 8

Table 9/13: Time schedule of the motor-glider ASK-16

Flight-No.	Date	Time (UTC)	comment
A2	21.3.85	0855-0927	broken off (data recording defect)
A3	21.3.85	1349-1453	
B1	23.3.85	0738-0824	broken off due to showers
B2	23.3.85	1252-1339	
B3	23.3.85	1416-1530	complete profile
C1	28.3.85	1403-1446	broken off due to showers
D1	29.3.85	0804-0928	
D2	29.3.85	1056-1147	

Table 9/14: Time schedule of the Bölkow 207

LfU-Landesanstalt für
Umweltschutz
Dr. Ahrens
Postfach 210752
Hertzstraße 173

7500 Karlsruhe 21

TU-Darmstadt
Institut für Anorg.
und Kernchemie
Prof. Bächmann
Hochschulstraße 4

6100 Darmstadt

Kernforschungszentrum Karlsruhe
IMK - Institut für Meteorologie
und Klimaforschung
Dr. Monika Bär
Postfach 3640
7500 Karlsruhe 1

Universität Stuttgart
Institut für Verfahrenstechnik
und Dampfkesselwesen
Dr. Baumbach
Pfaffenwaldring 23

7000 Stuttgart 80

UBA-Pilotstation Feldberg
Dr. Beilke
Frankfurter Str. 135

6050 Offenbach/Main

Energieversorgung Schwaben
Dr. Beising
Postfach 158
Kriegsbergstraße 32

7000 Stuttgart

NILU
Dr. Berg
P. O. Box 130

2001 Lillestroem

Norwegen

Landesanstalt für Umweltschutz
und Gewerbeaufsicht
Dr. Bockholt
Rheinallee 97 - 101

6500 Mainz

CEA-CEN
Dr. Carbonelle
Saclay

91191 Gif Sur Yvette Cedex

France

Universität Karlsruhe/
Kernforschungszentrum
Institut für Meteorologie und
Klimaforschung
Prof. Dr. F. Fiedler
Postfach 6380

7500 Karlsruhe 1

Kernforschungszentrum Karlsruhe
PEF-PL
Dr. Filby
Postfach 3640

7500 Karlsruhe 1

Universität Karlsruhe
Institut für Meteorologie
und Klimaforschung
Dipl.-Met. Franck
Postfach 6380

7500 Karlsruhe 1

Universität Stuttgart
Institut für Kernenergetik
Dr. Friedrich
Pfaffenwaldring 23

7000 Stuttgart 80

GSF - JRC - Ispra
Dr. Gaglione

I - 21020 Ispra(VA)

Italien

Eidg. Institut für Reaktorforschung
Abteilung 34
Dr. Gassmann

CH - 5303 Würenlingen

Schweiz

Geosens b. v.
P. O. B. 12067

NL - 3004 Rotterdam

Niederlande

Table 11/1: List of all participants of the TULLA experiment

Continuation Table 11/1

Universität Freiburg
Institut für Phys. Geographie
Dr. Goßmann

7800 Freiburg

Zentrum für Umweltschutz
der Universität
Dr. Jaeschke
Robert Mayer Straße

6000 Frankfurt/Main1

Umweltbundesamt
Pilotstation Schauinsland
Dr. Graul
Postfach 12 29

7815 Kirchzarten

Central Electricity Generating
Board
Dr. Marsh
Surrey KT 22 7SE

Leatherhead

G. B.

DG XII . CEC
Dr. Guillot
200 rue de la Loi

Brüssel

Belgien

NOAA ATDL
Dr. Mc. Millen
Post Office Box E
Oak Ridge, Tennessee 37631
U.S.A.

Badenwerk AG
DR. Häsler
Postfach 1680

7500 Karlsruhe

B A S F
Emissionsüberwachung
und Ökologie/Luft
Dr. Mutz

6700 Ludwigshafen

NOAA ATDL
Dr. Hicks
Post Office Box E

Oak Ridge, Tennessee 37631

U. S. A.

Neckarwerke AG
Dr. Necker
Postfach
Küferstraße 2

7300 Esslingen

Kernforschungszentrum Karlsruhe
IMK-Institut für Meteorologie
und Klimaforschung
Dr. Hübschmann

7500 Karlsruhe 1

Kernforschungszentrum Karlsruhe
IMK-Institut für Meteorologie
und Klimaforschung
Dipl.-Met. K. Nester

7500 Karlsruhe 1

Kernforschungszentrum Karlsruhe
IMK-Institut für Meteorologie
und Klimaforschung
Dipl.-Met. von Holleuffer-Kypke
Postfach 3640

7500 Karlsruhe 1

LfU-Landesanstalt für
Umweltschutz
Dr. Ohländer
Postfach 210752
Hertzstraße 173

7500 Karlsruhe 21

Wetterdienstschule
Dipl.-Met. Jaeneke
Villenstr. 15

6730 Neustadt/Weinstraße

DFVLR
Dr. Paffrath

8031 Oberpfaffenhofen/
Weßling

Continuation Table 11/1

DFVLR
Dr. Peters
8031 Oberpfaffenhofen/
Weßling

Kernforschungszentrum Karlsruhe
IMK-Institut für Meteorologie
und Klimaforschung
Dr. Thomas

7500 Karlsruhe 1

Institut für Hygiene
und Epidemiologie
Dr. de Saeger
rue j. wytsmann 14

1050 Brüssel

Belgien

Studiecentrum voor Kernenergie
Environmental Research Section
Dr. Vanderborght
Boeretang 200

B - 2400 Mol

Belgien

GFS - JRC - Ispra
Dr. Sandroni

I - 21020 Ispra (VA)

Italien

Universität Karlsruhe
IMK-Institut für Meteorologie
und Klimaforschung
Dr. Walk

7500 Karlsruhe 1

Kernforschungszentrum Karlsruhe
AFAS
Dr. Schufmann
Postfach 3640

7500 Karlsruhe

Kernforschungszentrum Karlsruhe
IMK-Institut für Meteorologie
und Klimaforschung
Dipl.-Ing. Weppner

7500 Karlsruhe 1

Deutscher Wetterdienst
Medizinmeteorologische
Forschungsstelle
Dr. Schulz
Stefan Meier Straße 4

7800 Freiburg i. Br.

Argonne Nat. Lab.
Dr. Wesley
9700 South Cass
Argonne, Illinois 60439

U. S. A.

Universität Hohenheim
Institut für Physik
Prof. Schreiber
Postfach 700562

7000 Stuttgart 70

Universität Hohenheim
Institut für Physik
Prof. Wieser
Postfach 700567

7000 Stuttgart 70

Frauenhofer-Institut für atmosphärische Umweltforschung
Prof. Dr. Seiler
Kreuxeckbahnstr. 19

8100 Garmisch-Partenkirchen

Kernforschungszentrum Karlsruhe
IMK-Institut für Meteorologie
und Klimaforschung
Dipl.-Met. Zimmer
Postfach 3640
7500 Karlsruhe 1

GSF - JRC -Ispra
Dr. Stingele

I - 21020 Ispra(VA)

Italien

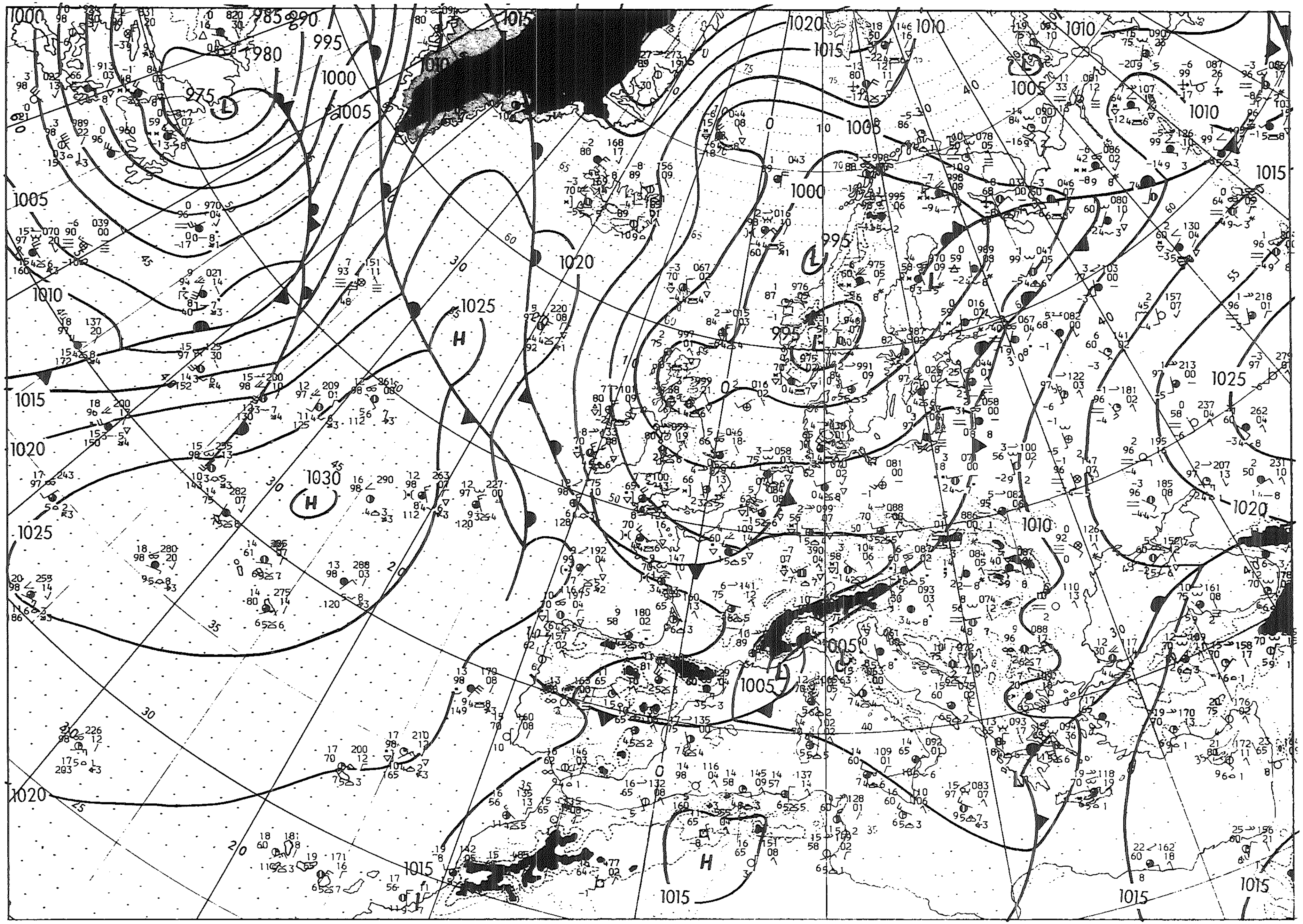


Figure 4/1: Surface chart of 15.3.1985 12 UTC

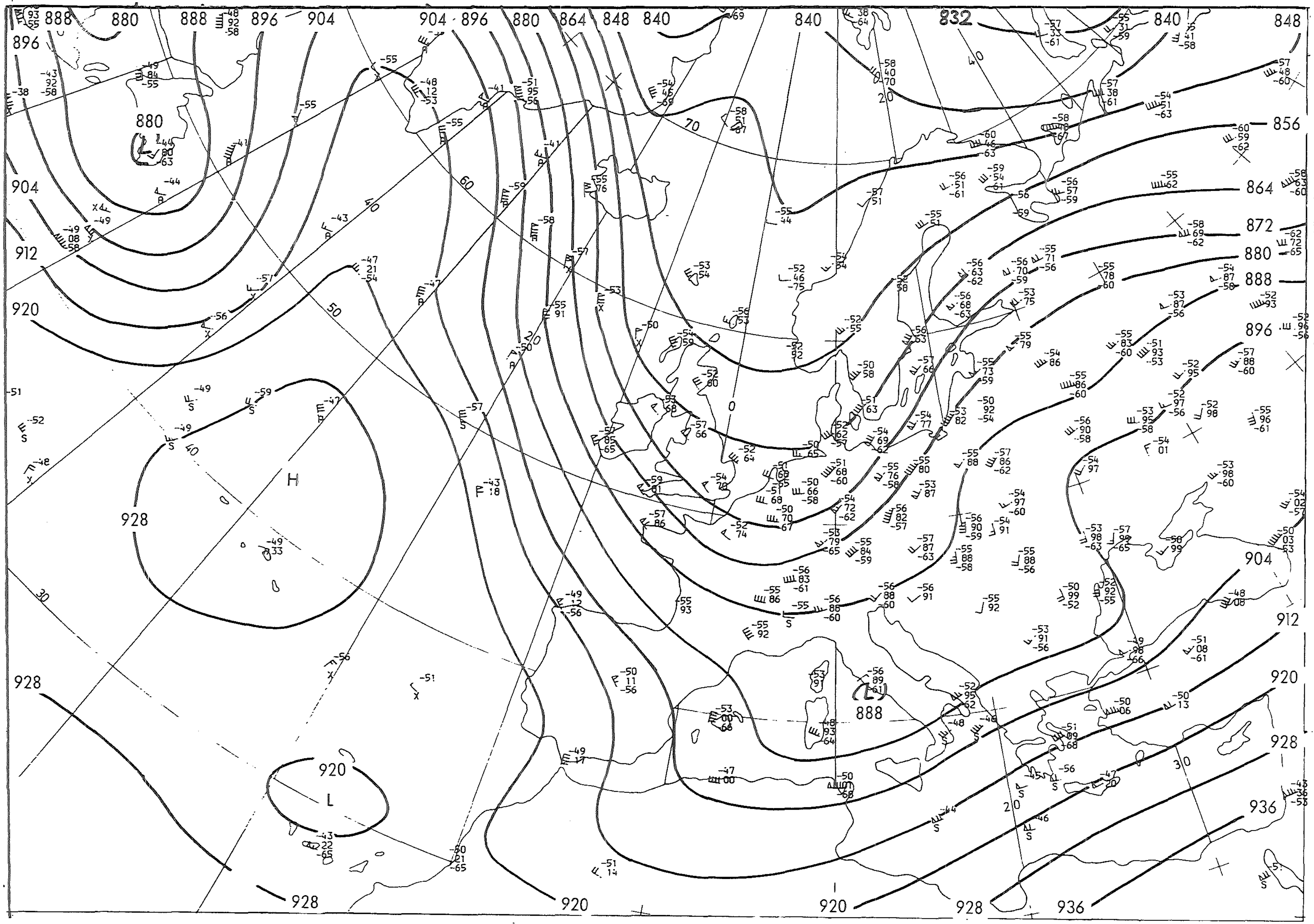


Figure 4/2: Pressure surface 300 hPa of 15.3.1985 00 UTC

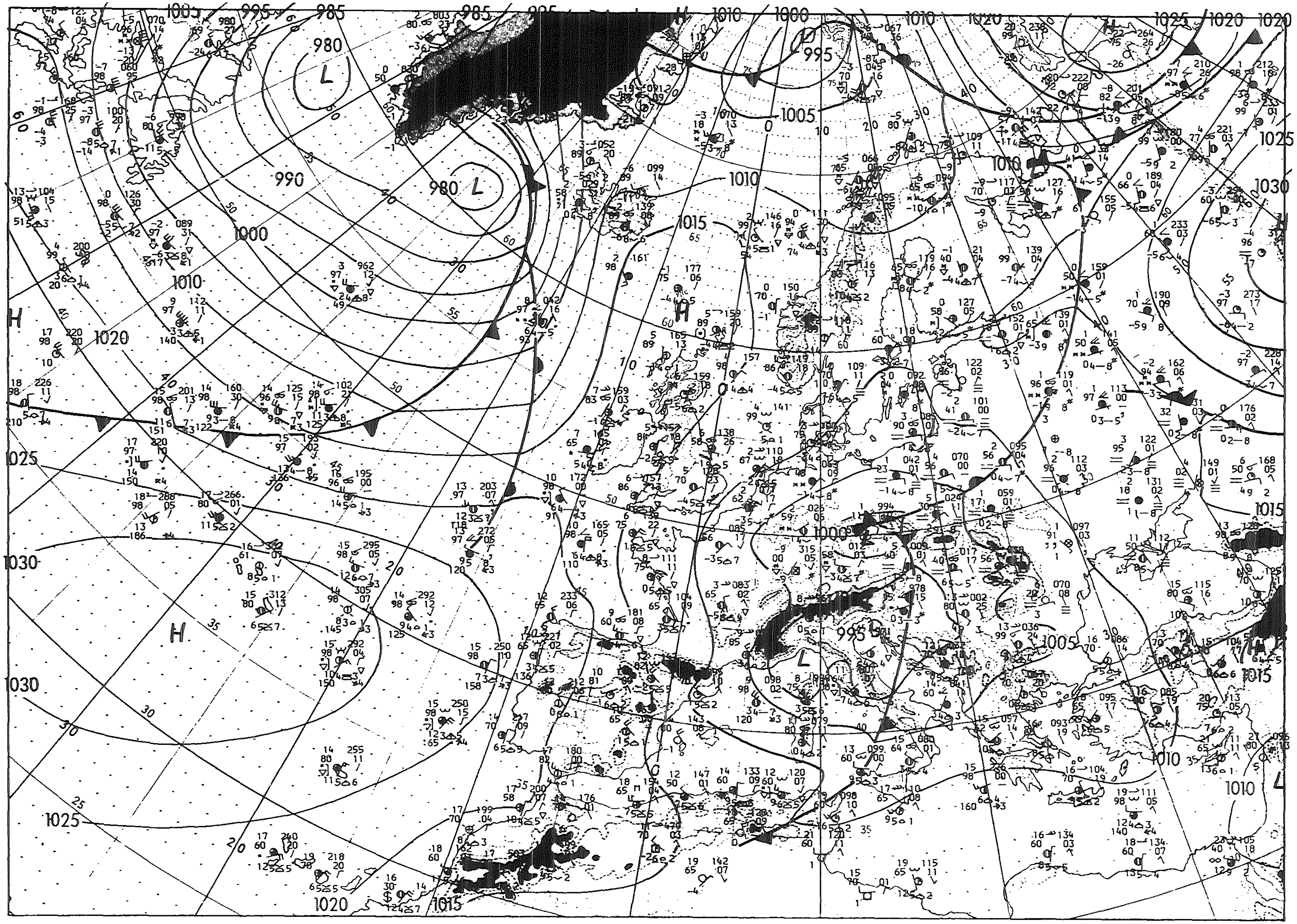


Figure 4/3: Surface chart of 17.3.1985 12 UTC

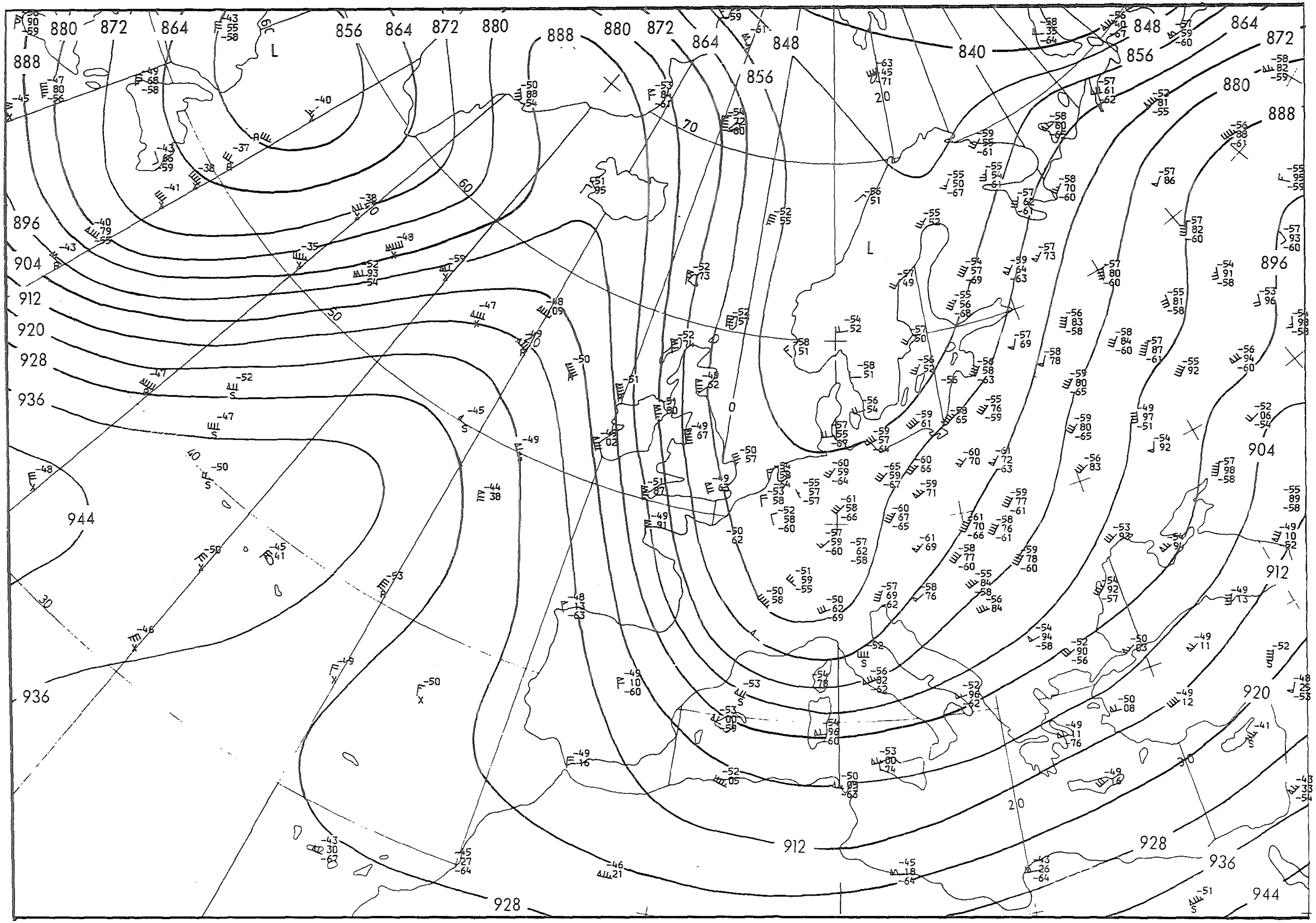


Figure 4/4: Pressure surface 300 hPa of 17.3.1985 00 UTC

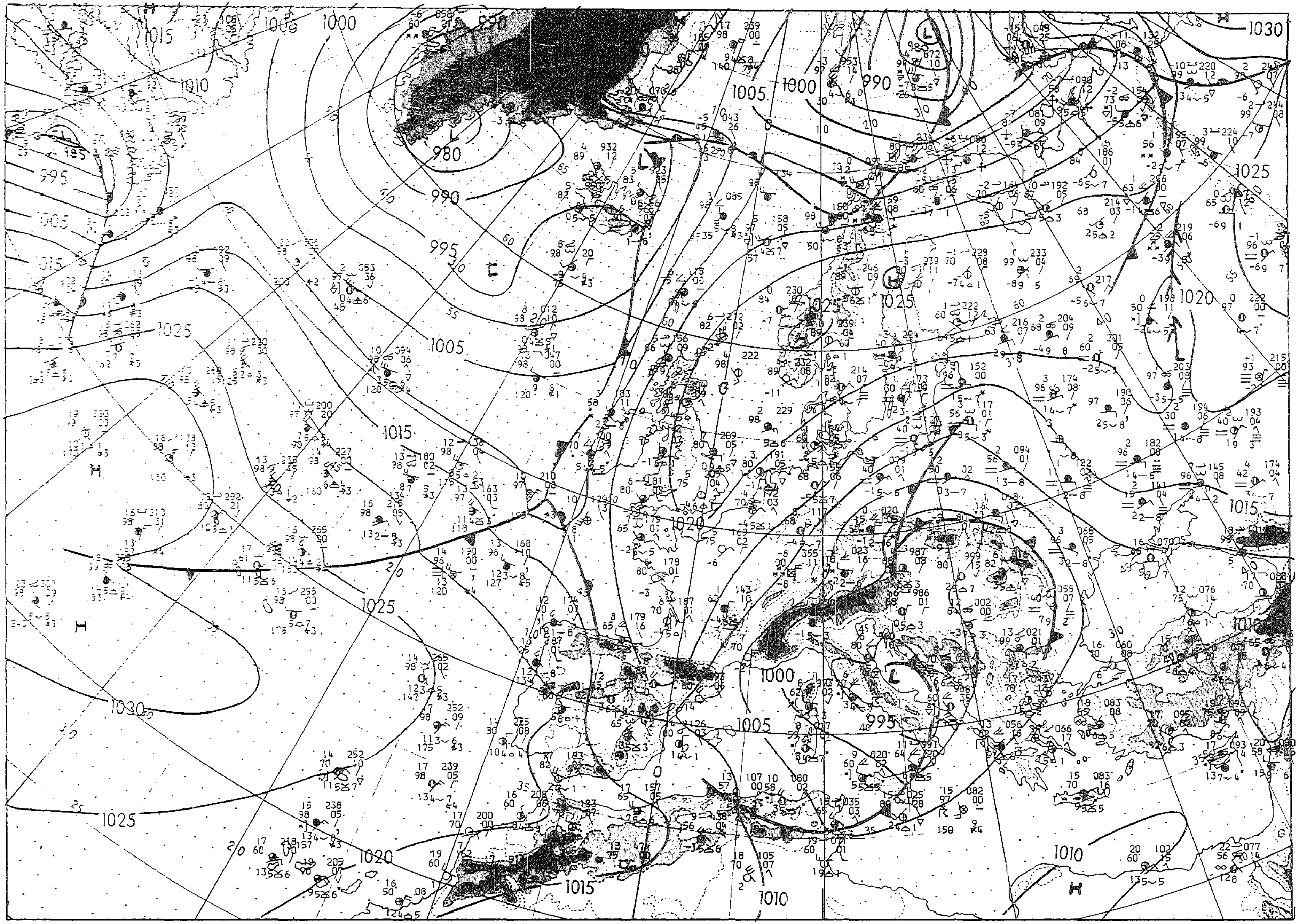


Figure 4/5: Surface chart of 18.3.1985 12 UTC

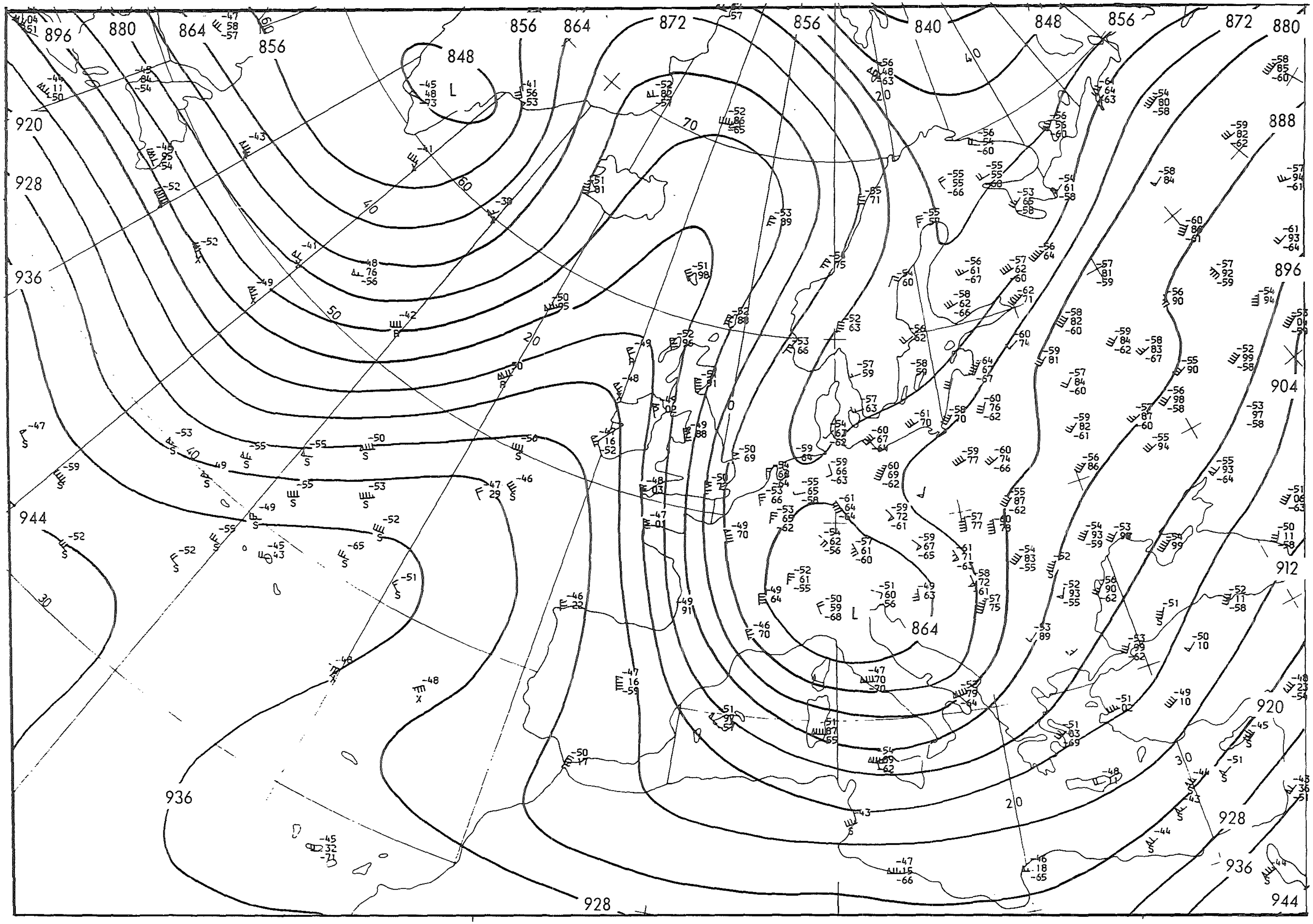


Figure 4/6: Pressure surface 300 hPa of 18.3.1985 00 UTC

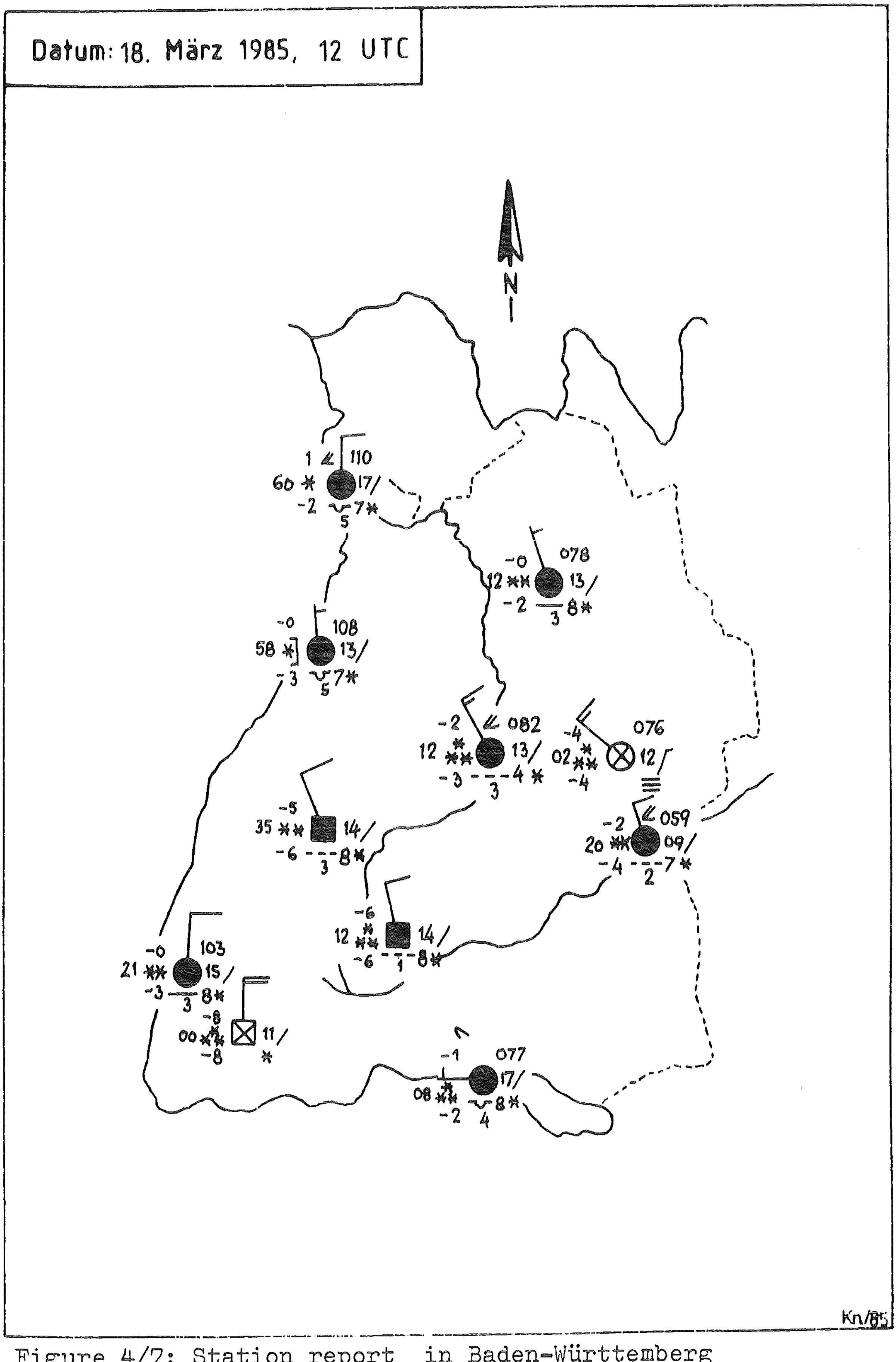


Figure 4/7: Station report in Baden-Württemberg
of 18.3.1985 12 UTC

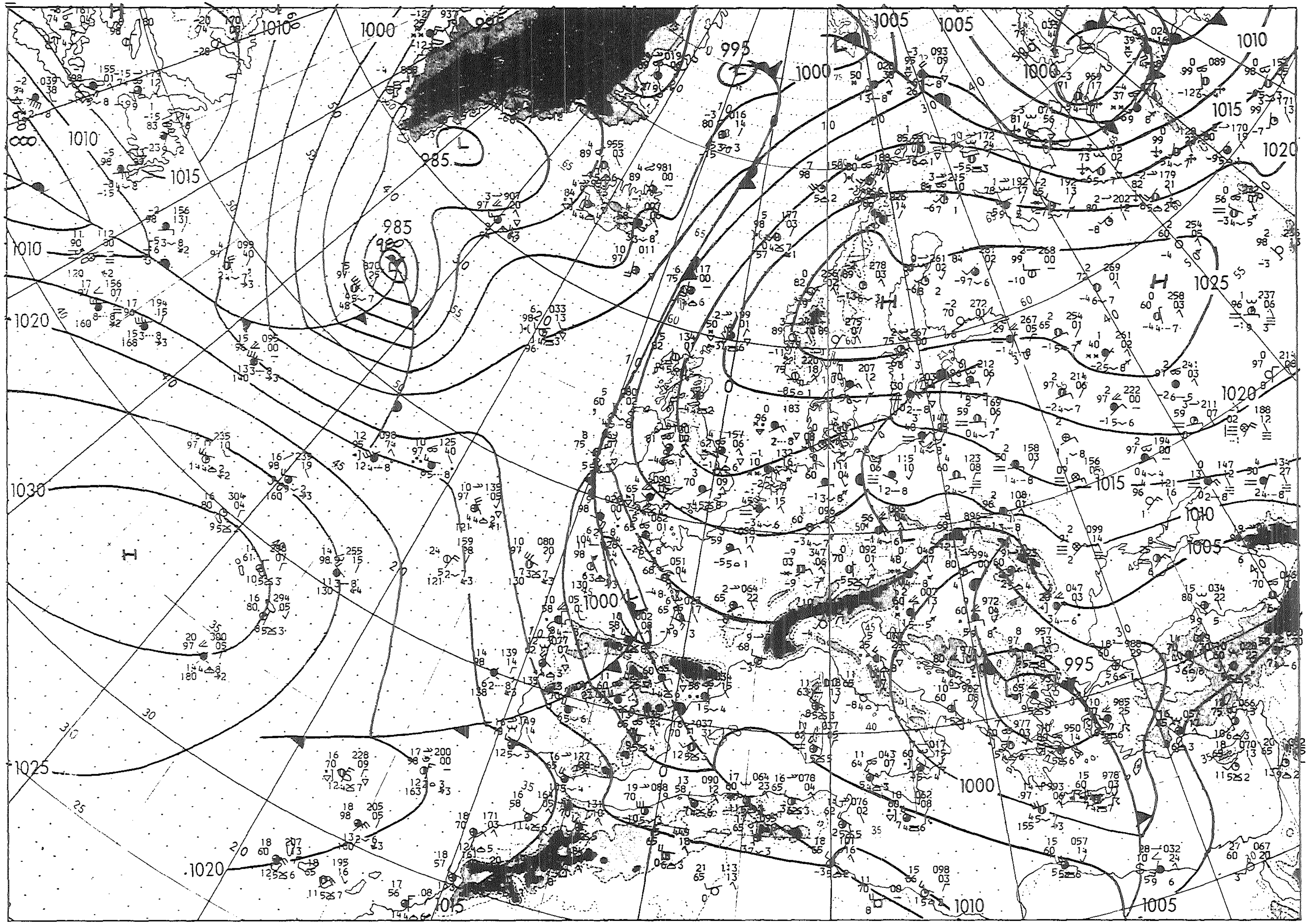


Figure 4/8: Surface chart of 19.3.1985 12 UTC

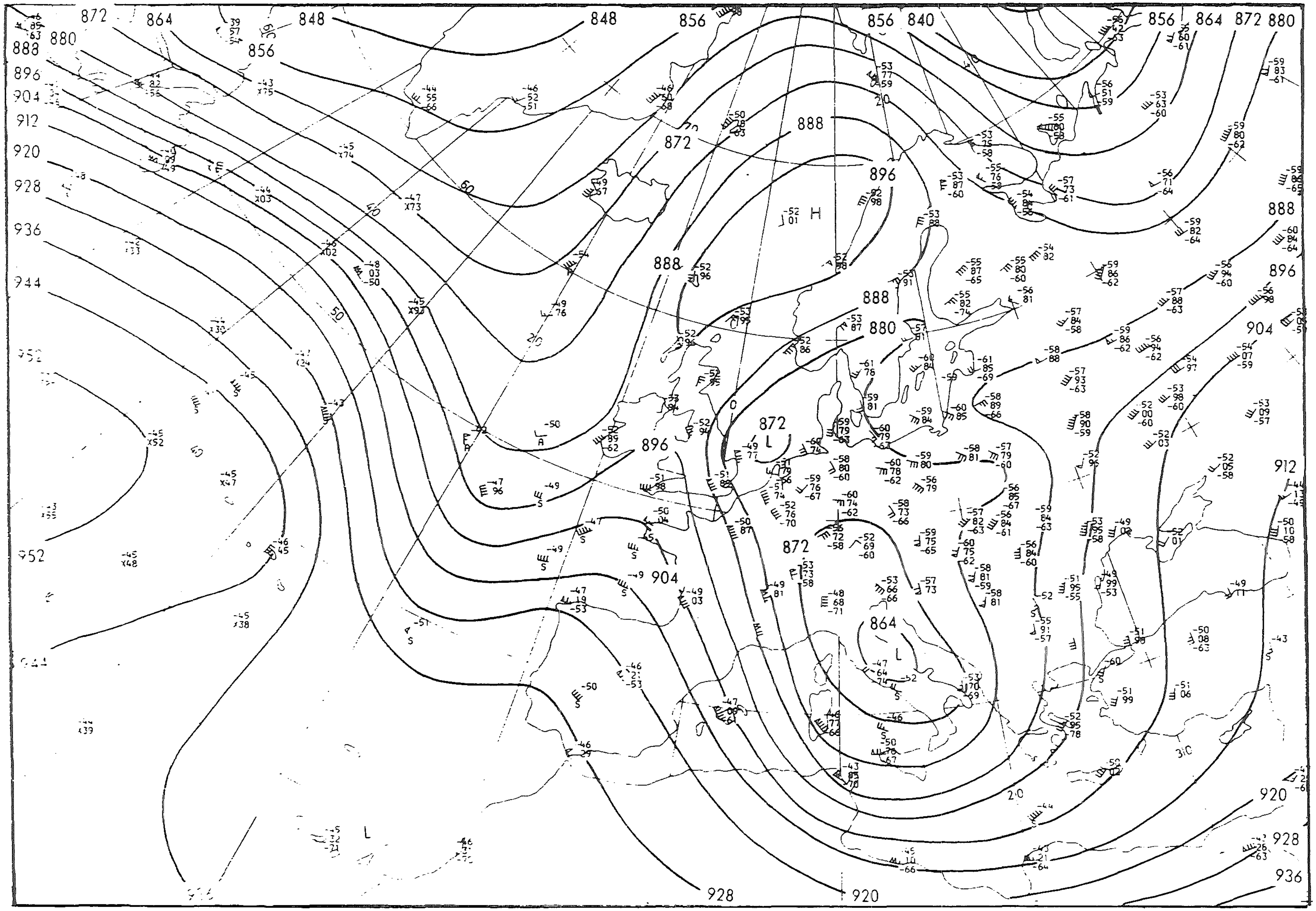


Figure 4/9: Pressure surface 300 hPa of 19.3.1985 00 UTC

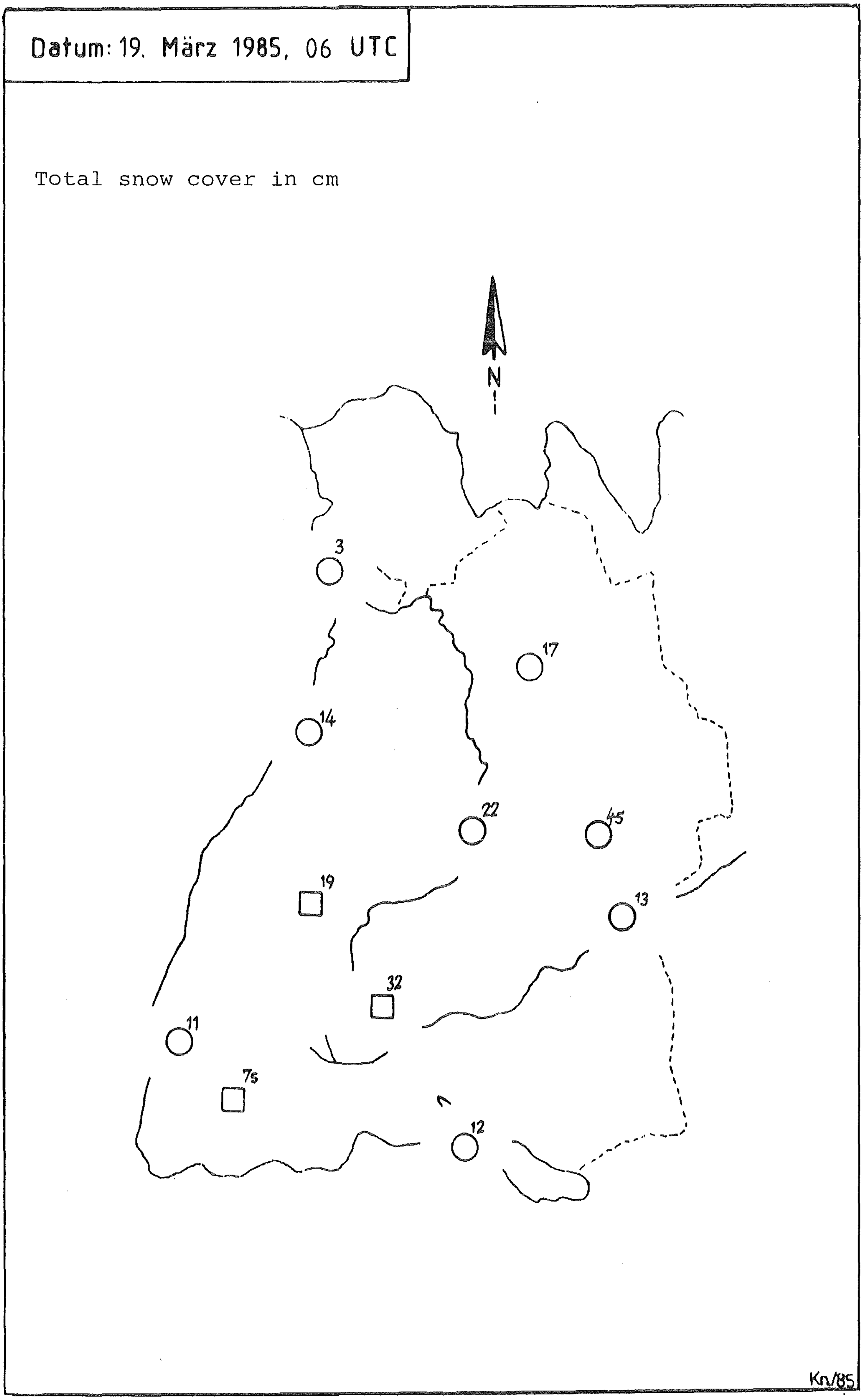


Figure 4/10: Station report in Baden-Württemberg
of 19.3.1985 06 UTC

Datum: 19. März 1985, 12 UTC

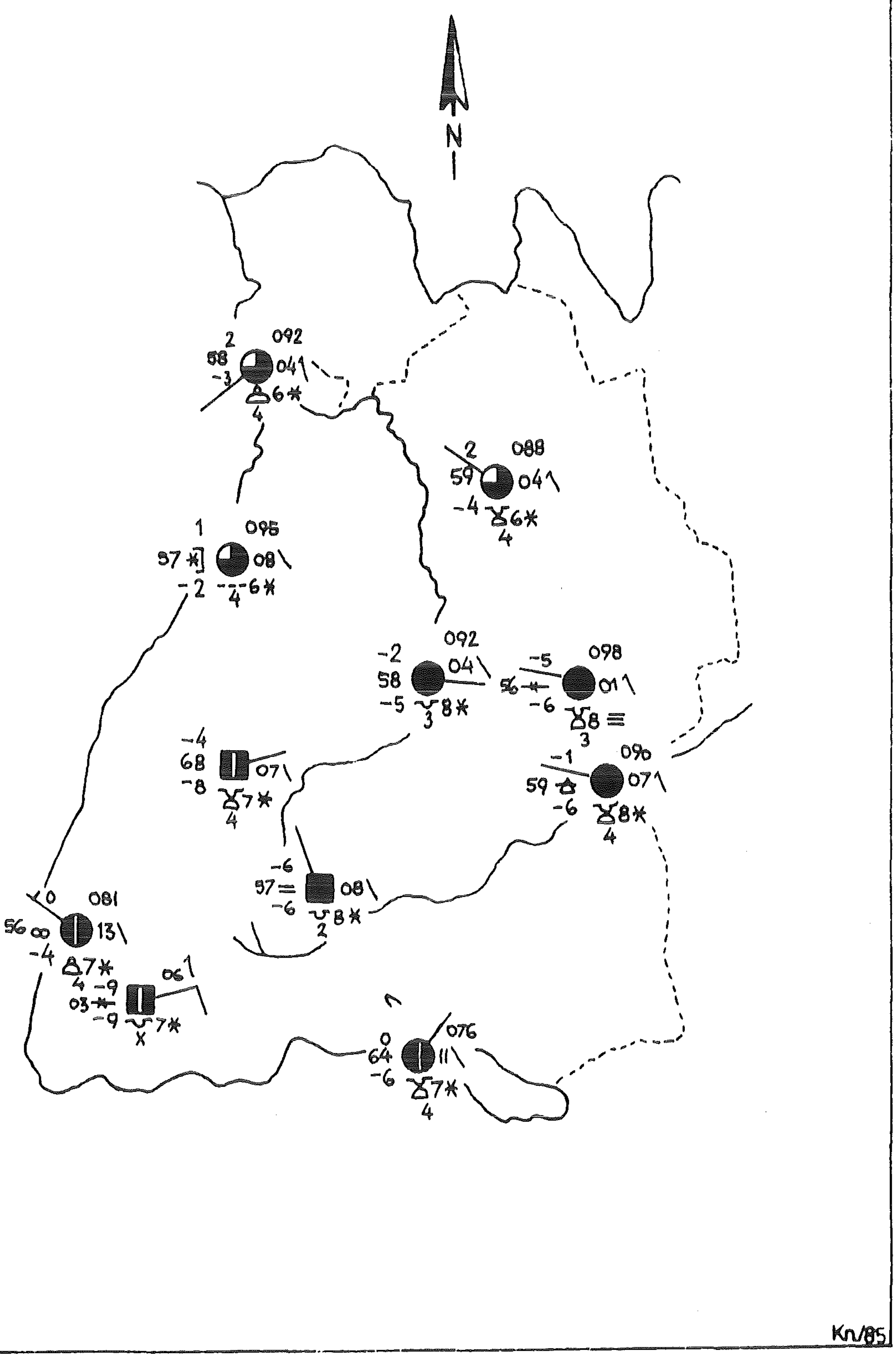


Figure 4/11: Station report in Baden-Württemberg of 19.3.1985 12 UTC

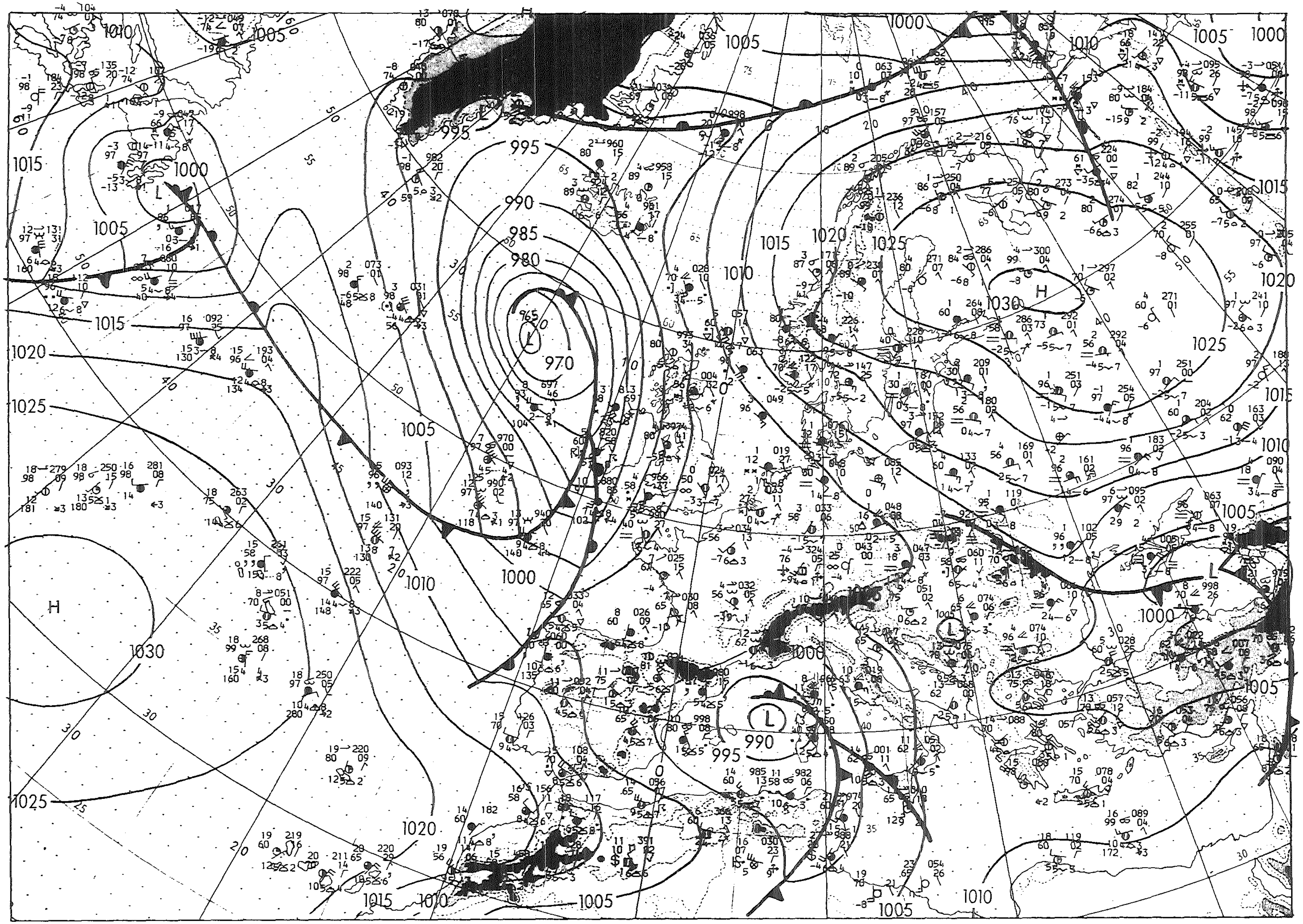


Figure 4/12: Surface chart of 20.3.1985 12 UTC

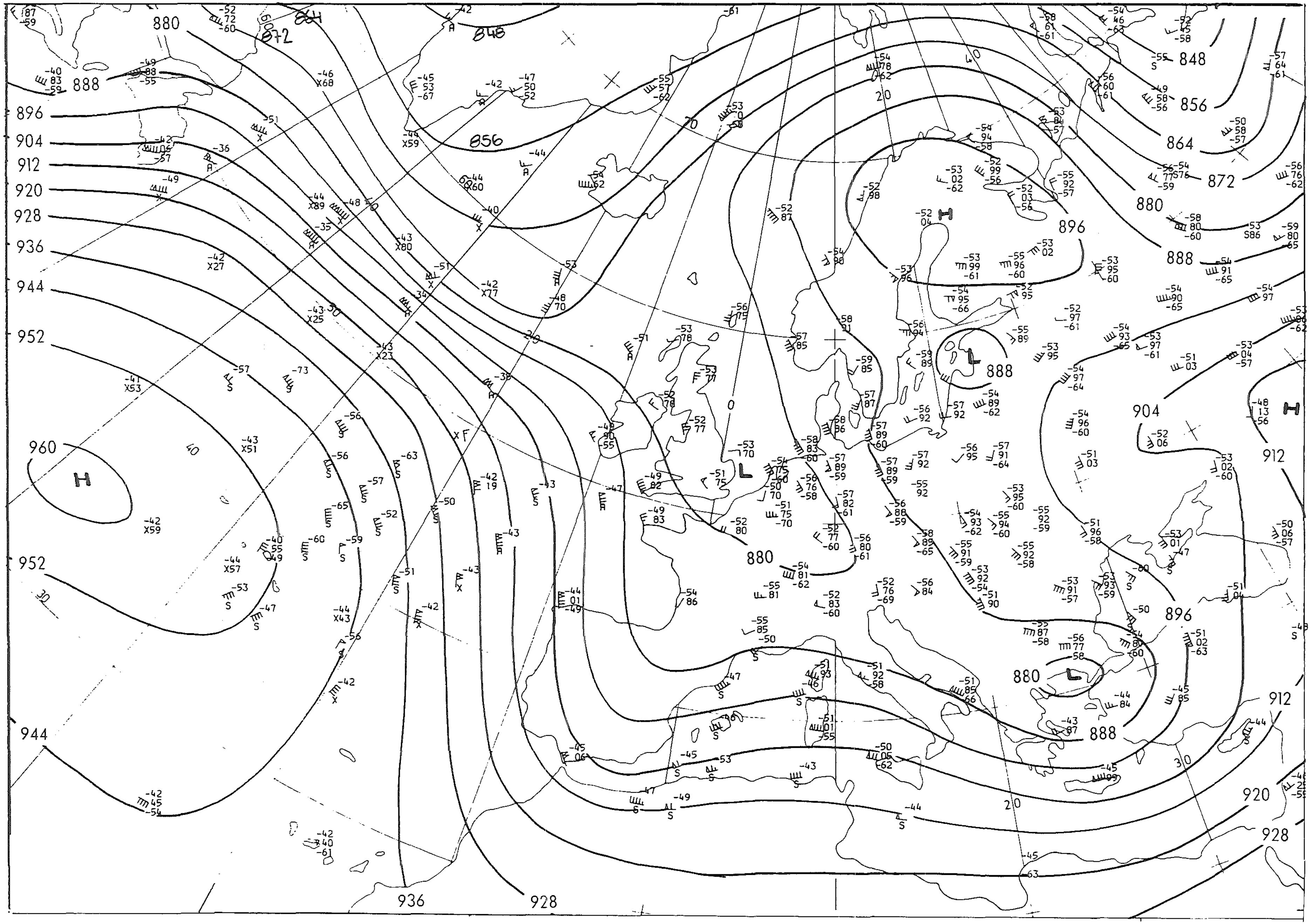


Figure 4/13: Pressure surface 300 hPa of 20.3.1985 00 UTC

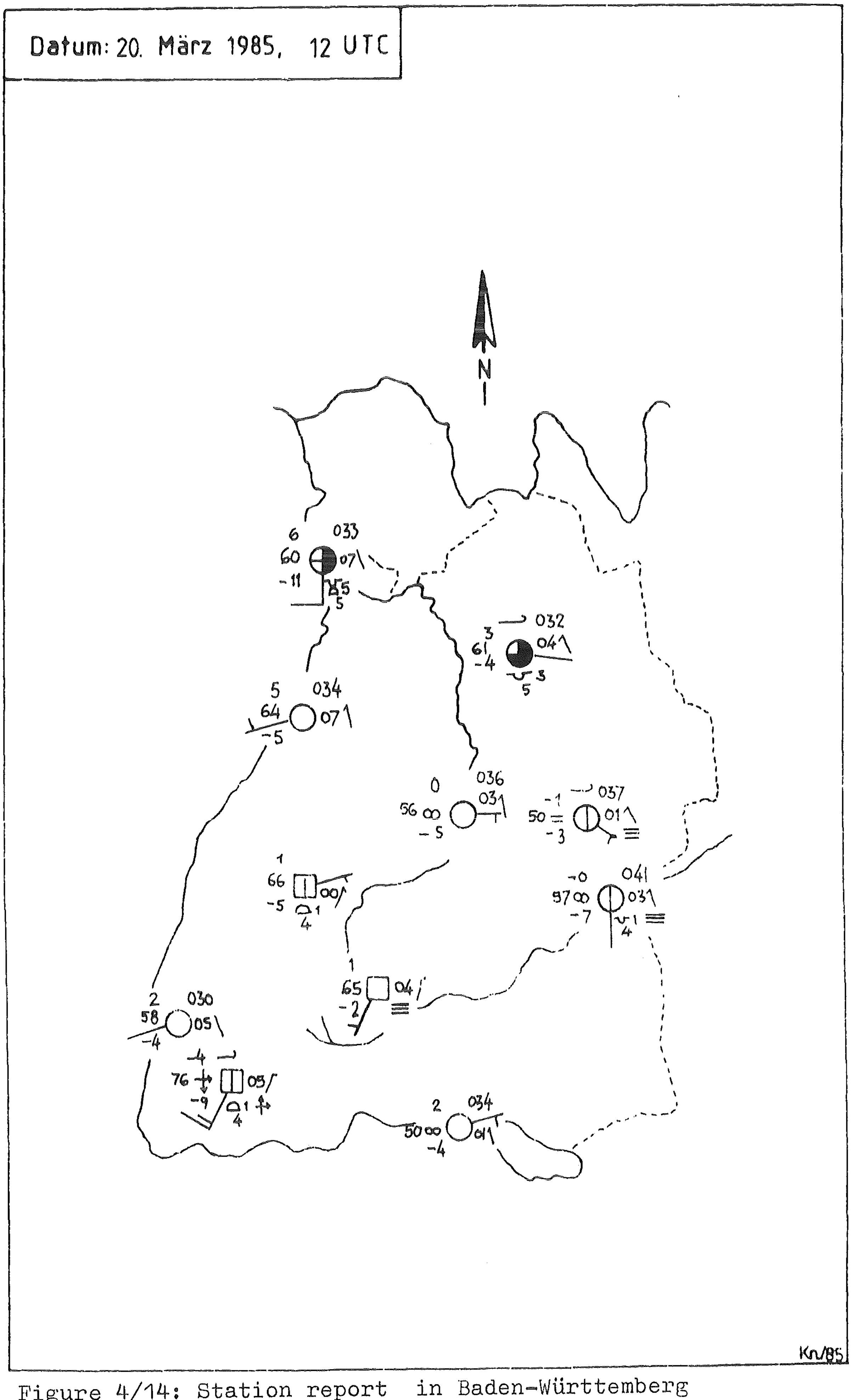


Figure 4/14: Station report in Baden-Württemberg of 20.3.1985 12 UTC

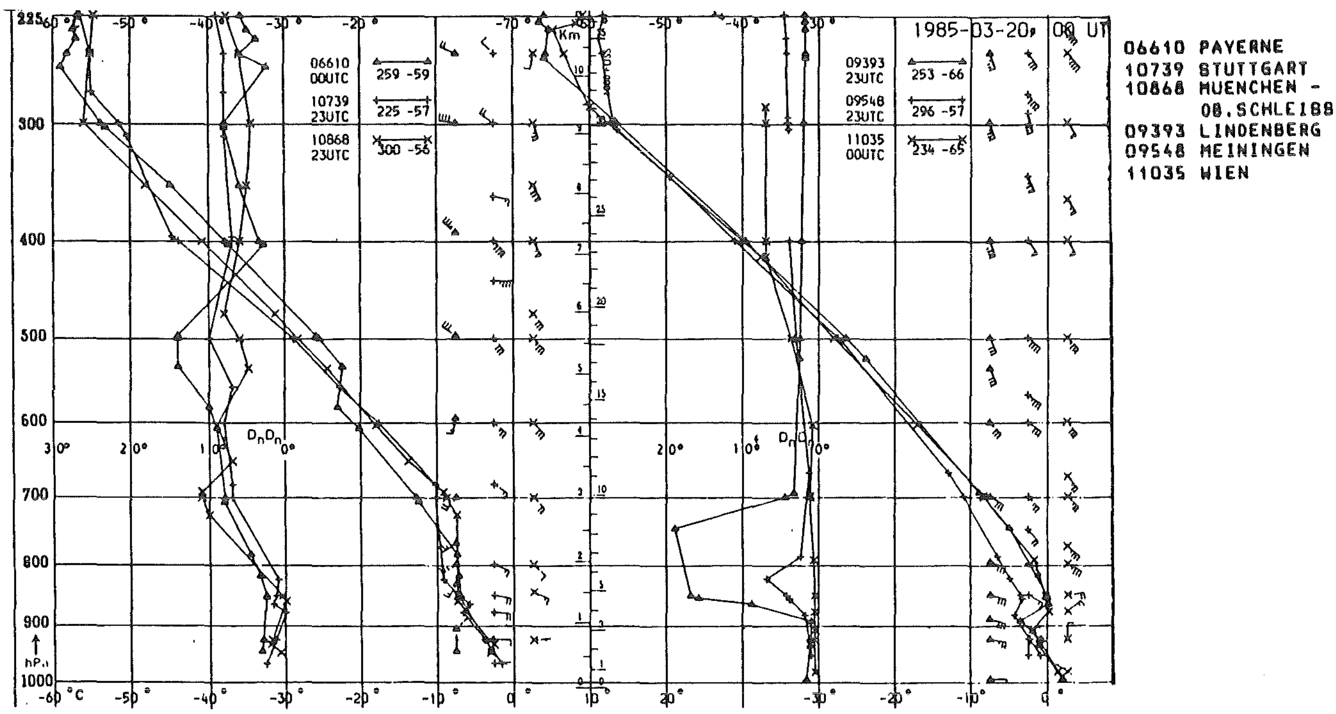


Figure 4/15: Radio-sonde ascents of 20.3.85 00 UTC

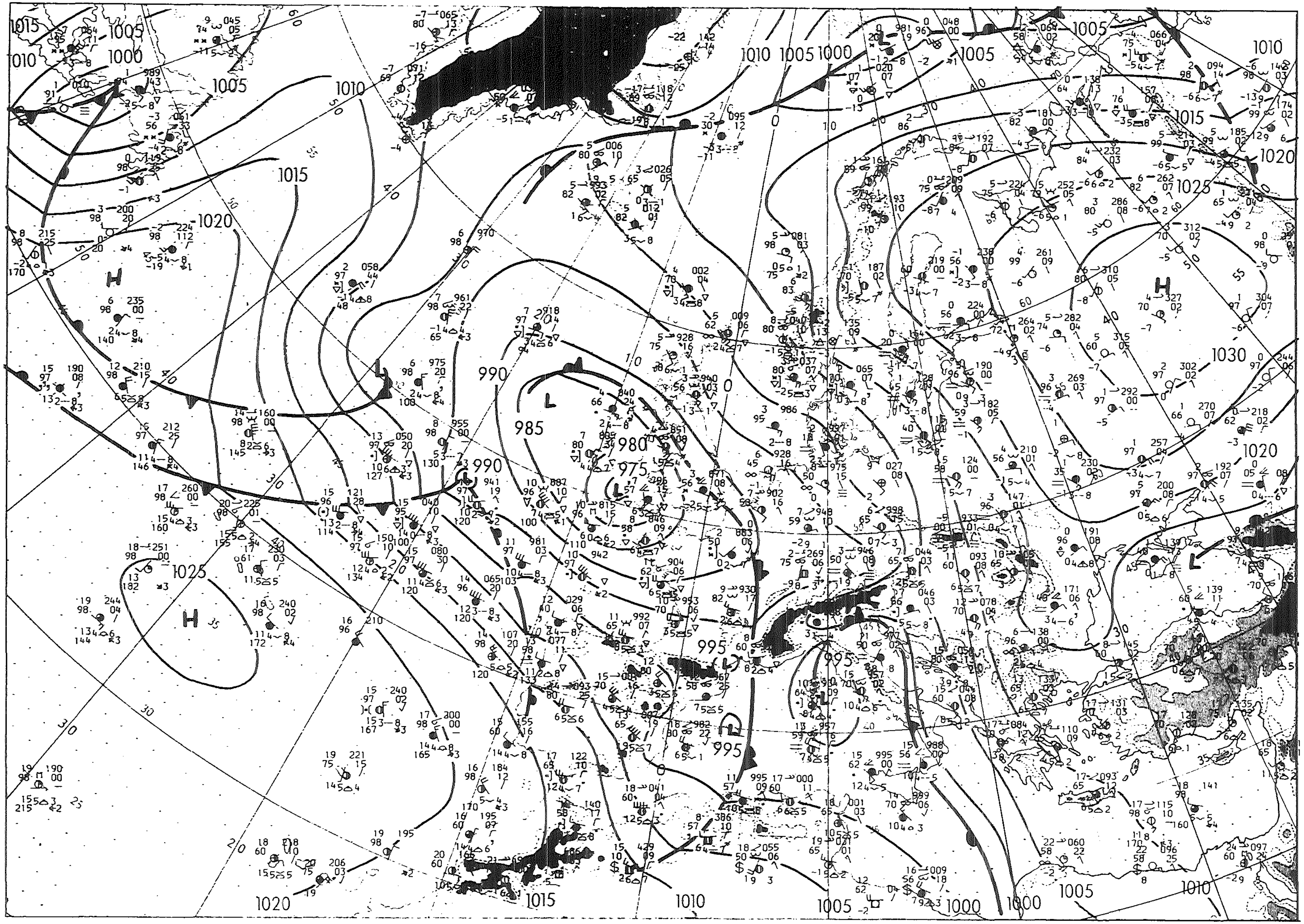


Figure 4/16: Surface chart of 21.3.1985 12 UTC

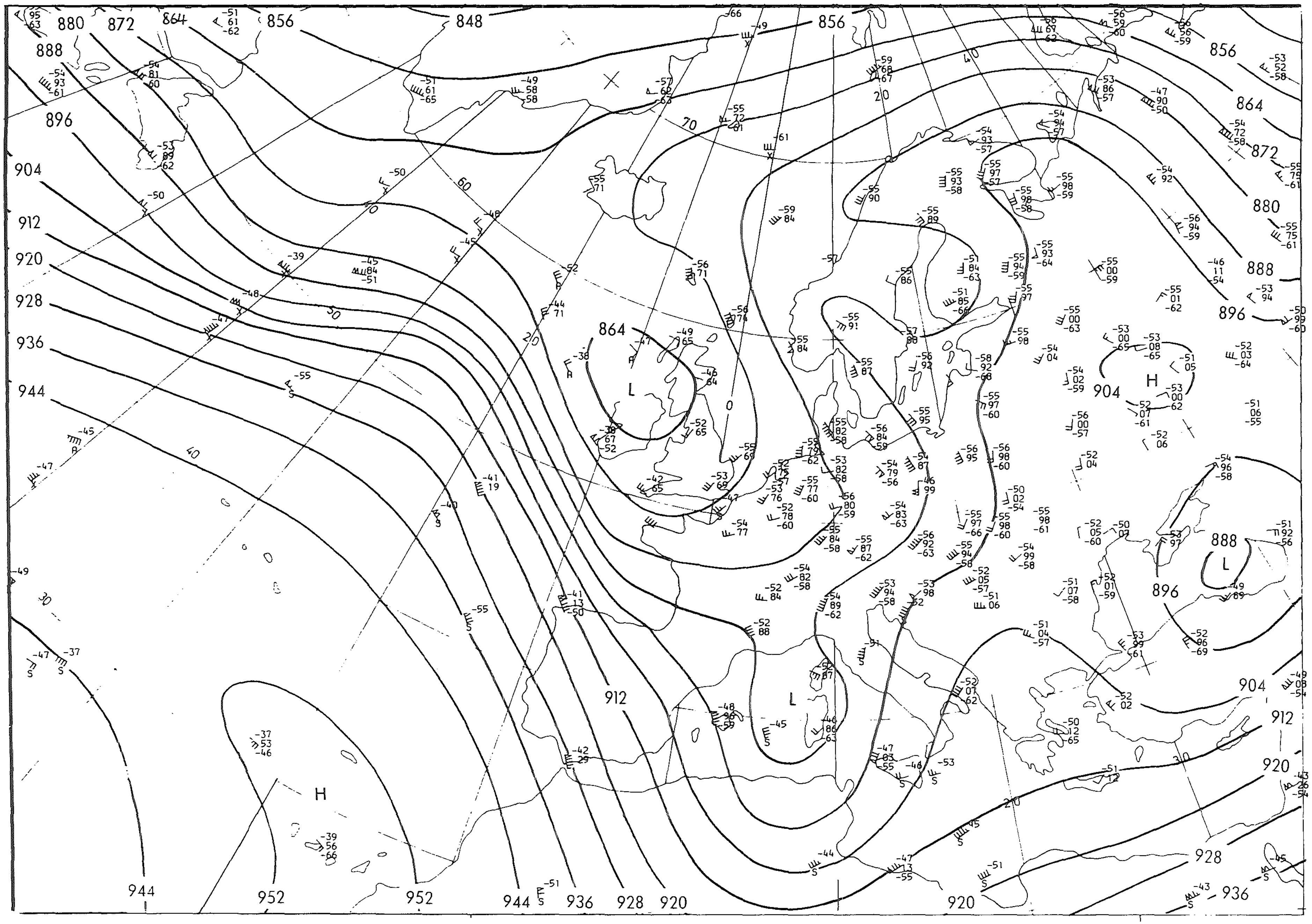


Figure 4/17: Pressure surface 300 hPa of 21.3.1985 00 UTC

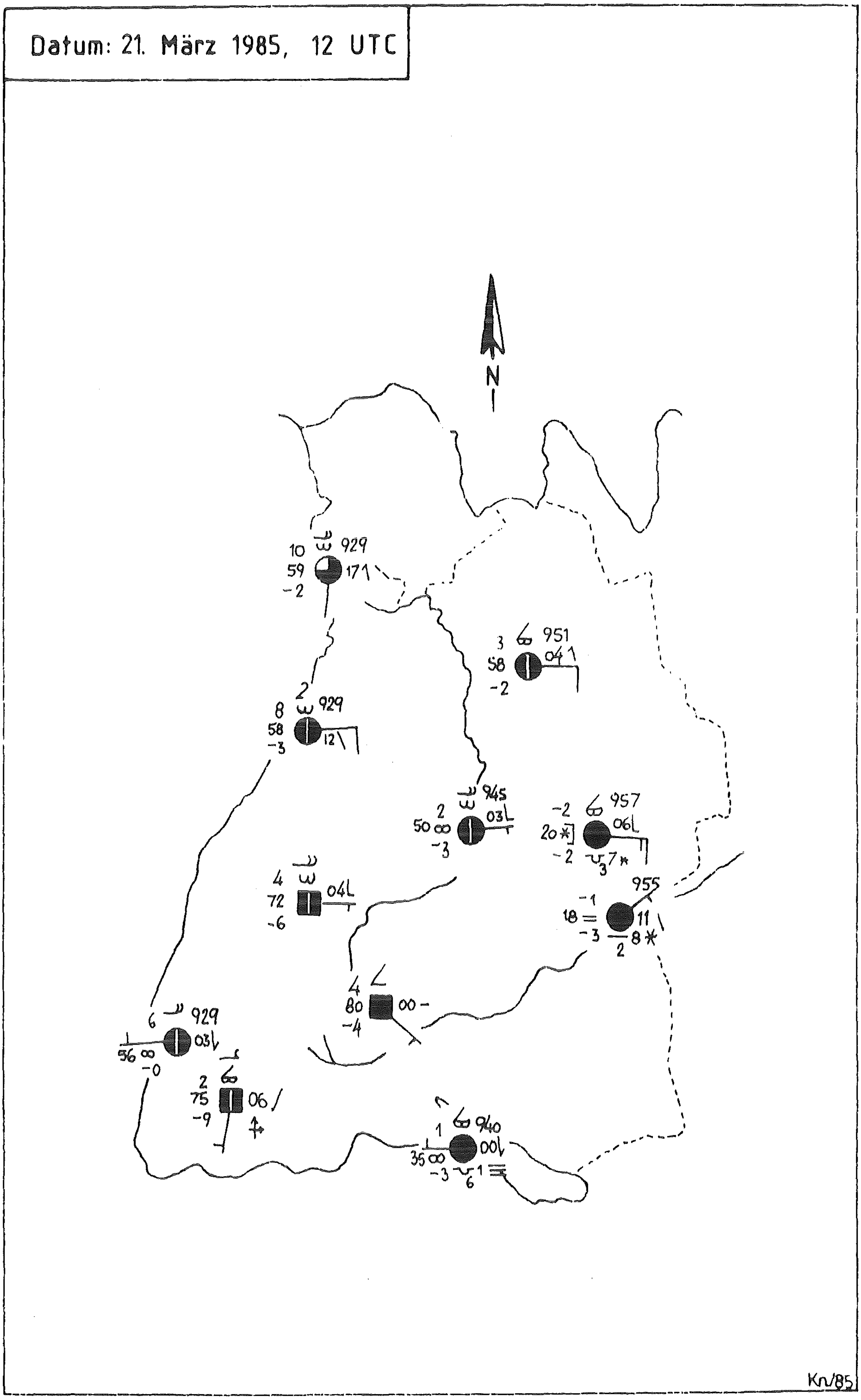


Figure 4/18: Station report in Baden-Württemberg of 21.3.1985 12 UTC

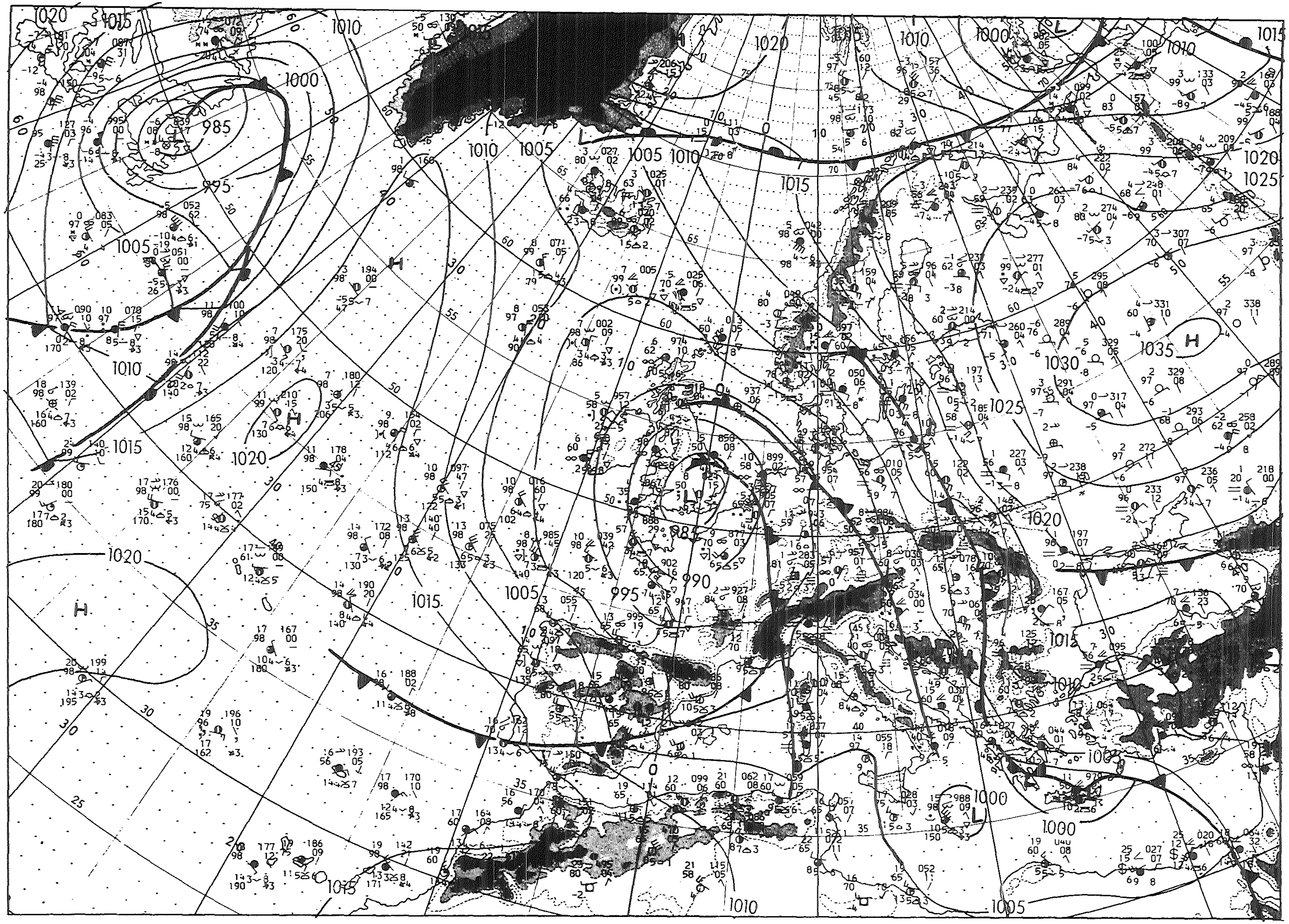


Figure 4/19: Surface chart of 22.3.1985 12 UTC

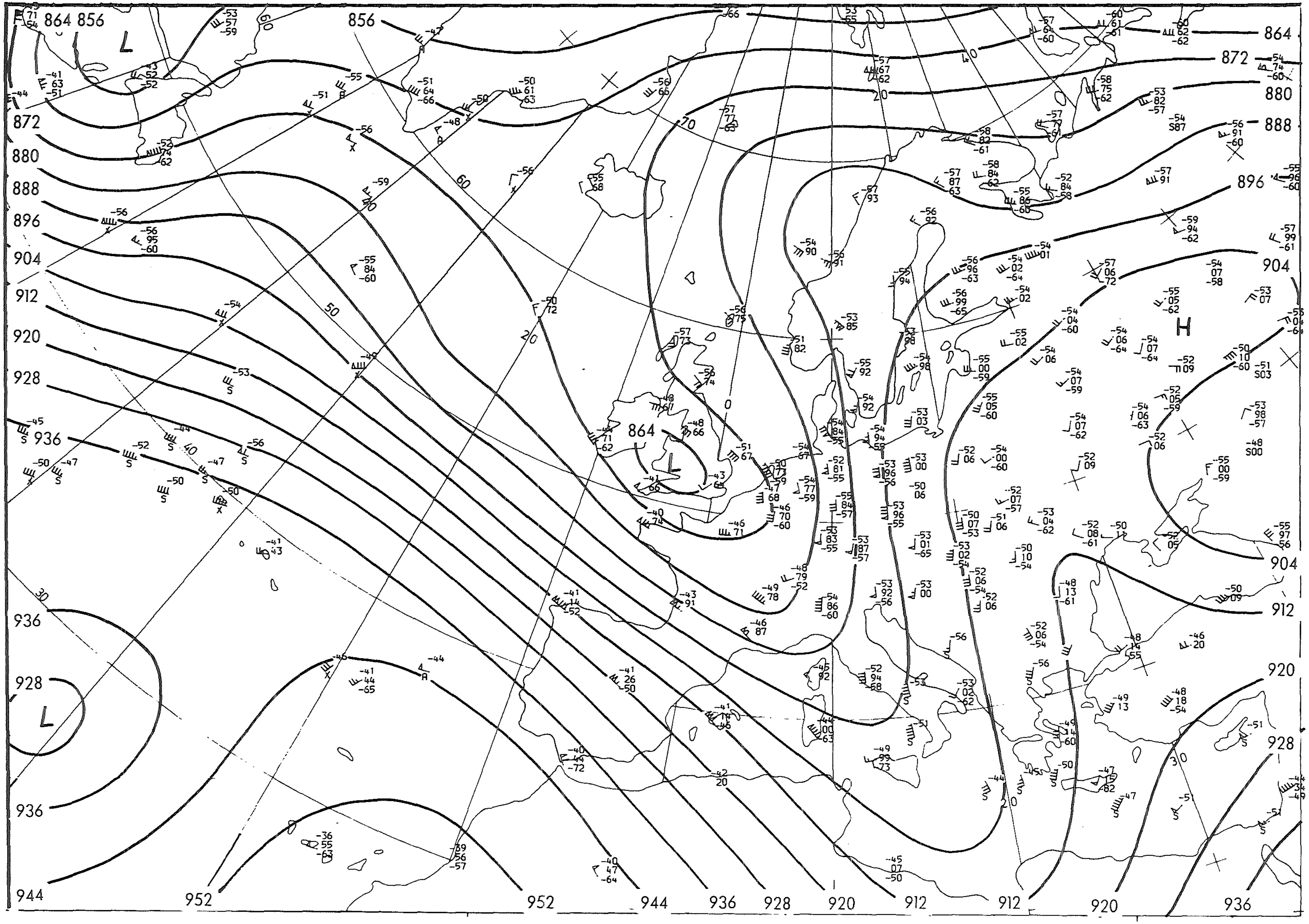


Figure 4/20: Pressure surface 300 hPa of 22.3.1985 00 UTC

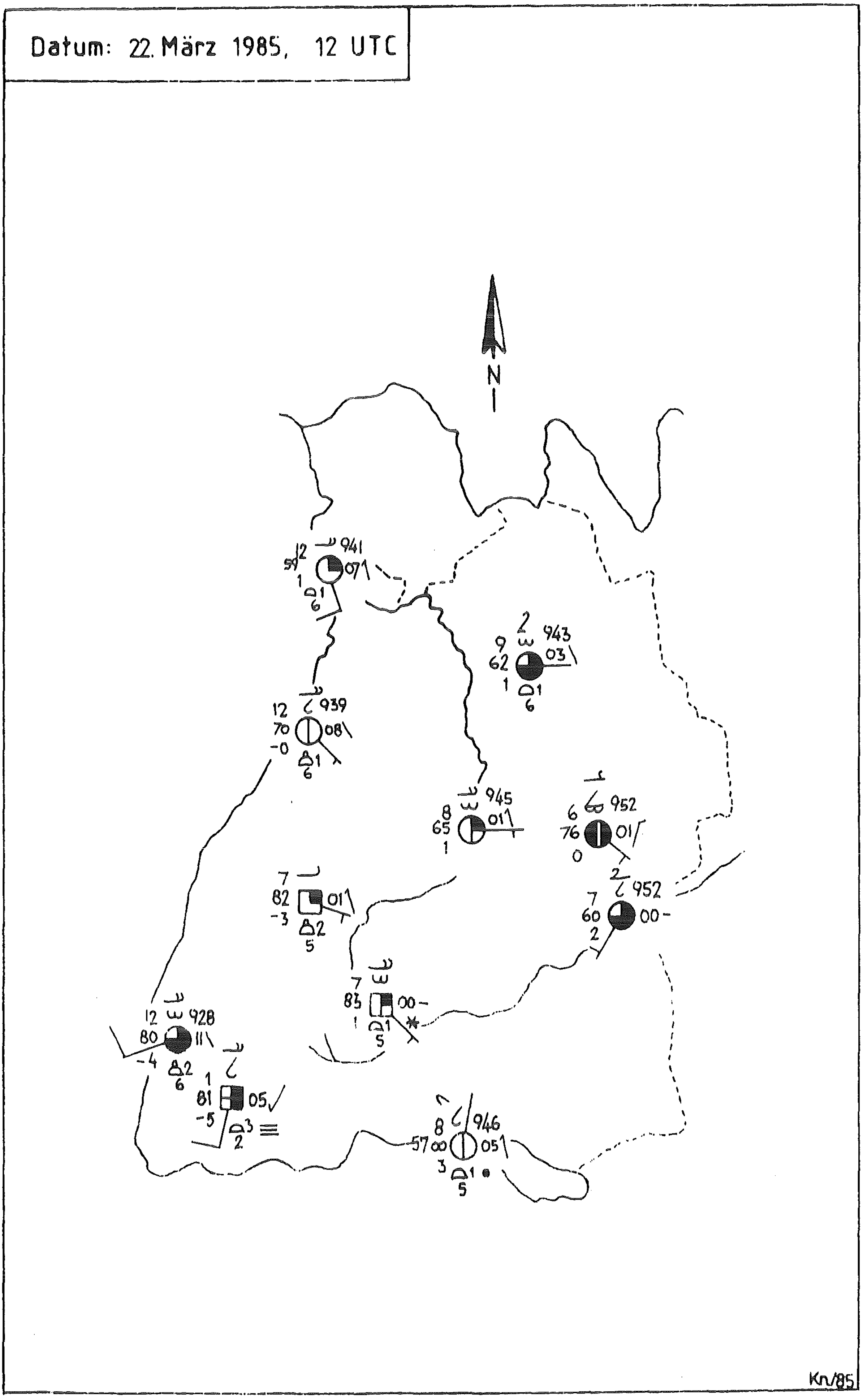


Figure 4/21: Station report in Baden-Württemberg of 22.3.1985 12 UTC

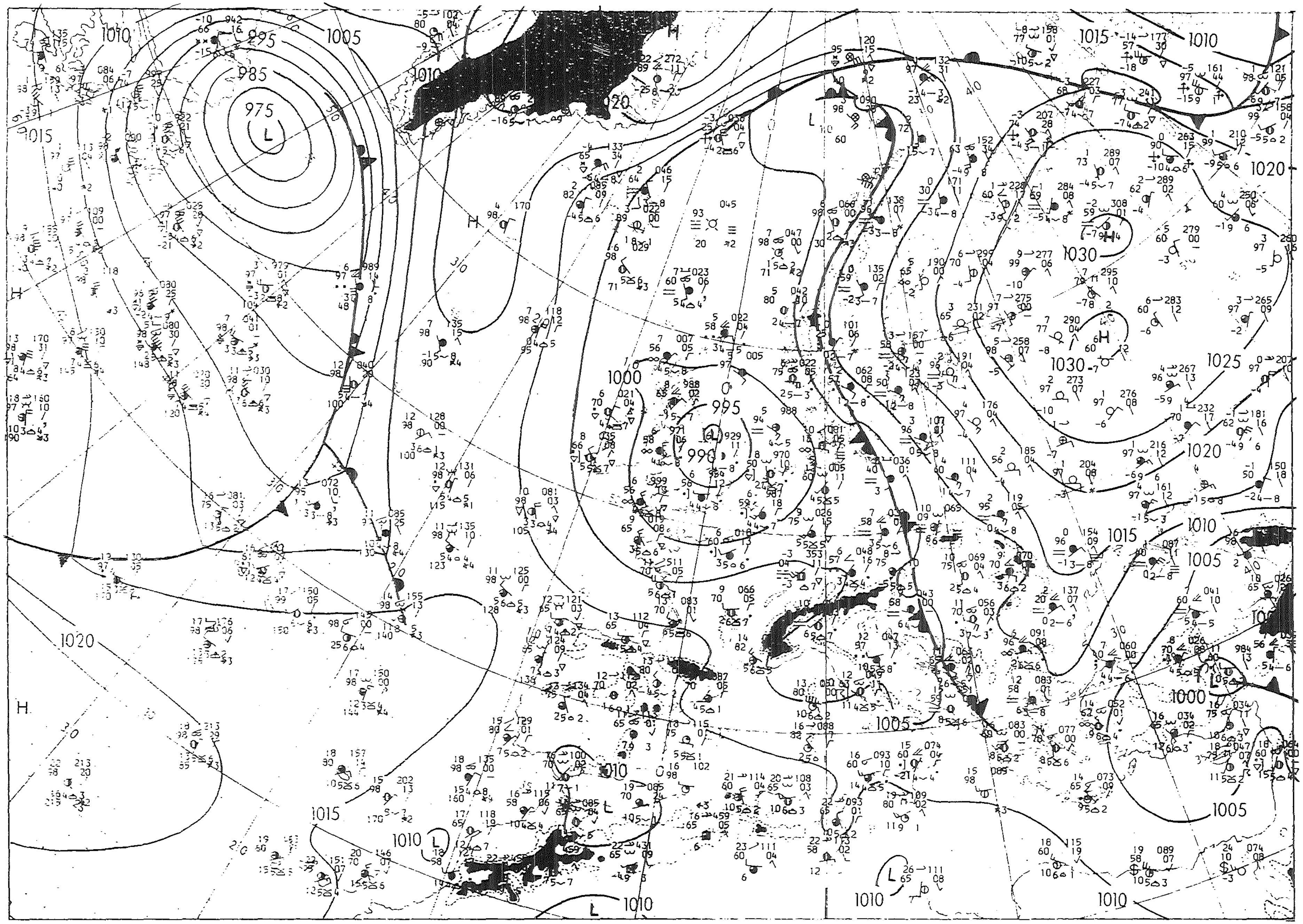


Figure 4/22: Surface chart of 23.3.1985 12 UTC

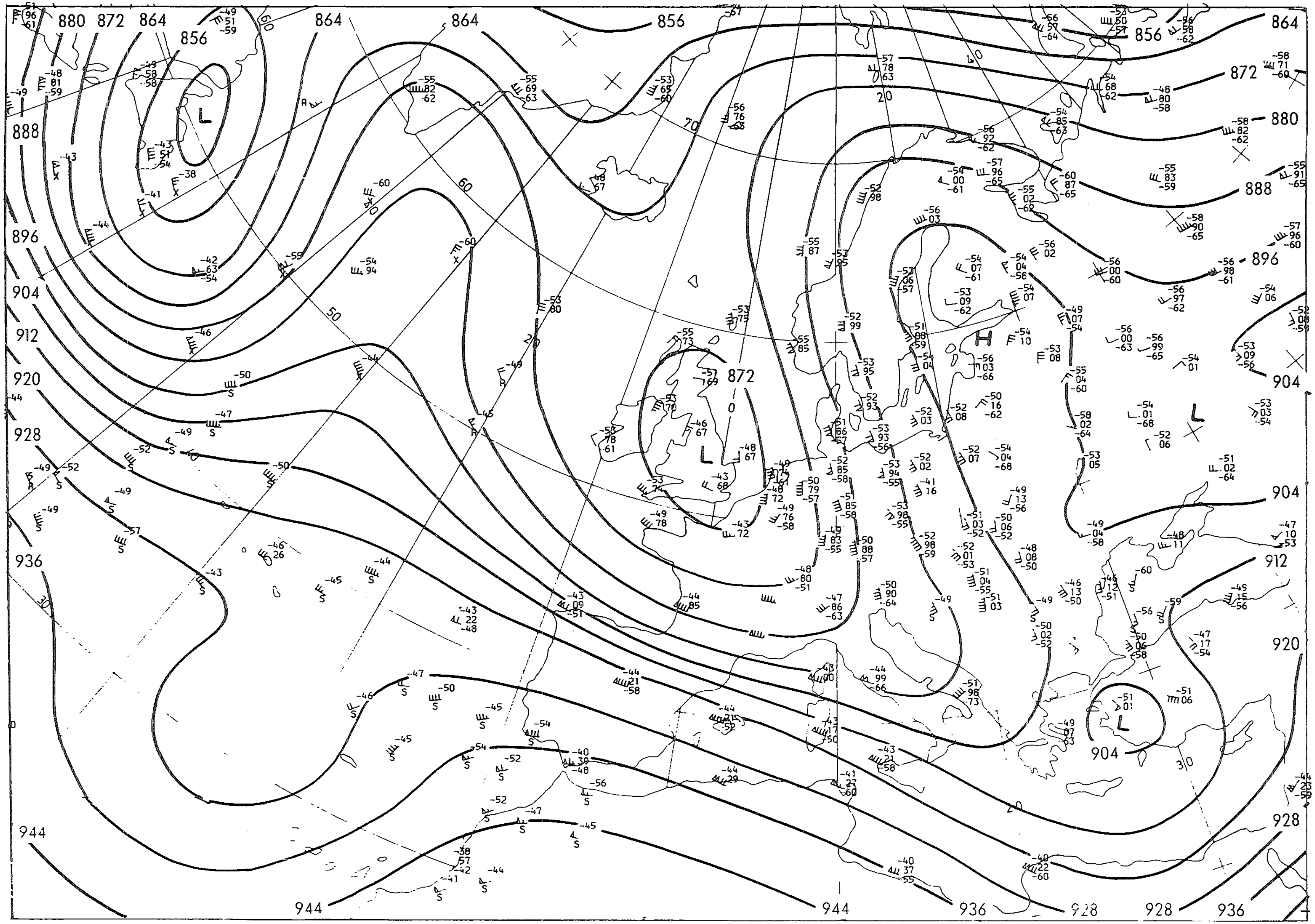


Figure 4/23: Pressure surface 300 hPa of 23.3.1985 00 UTC

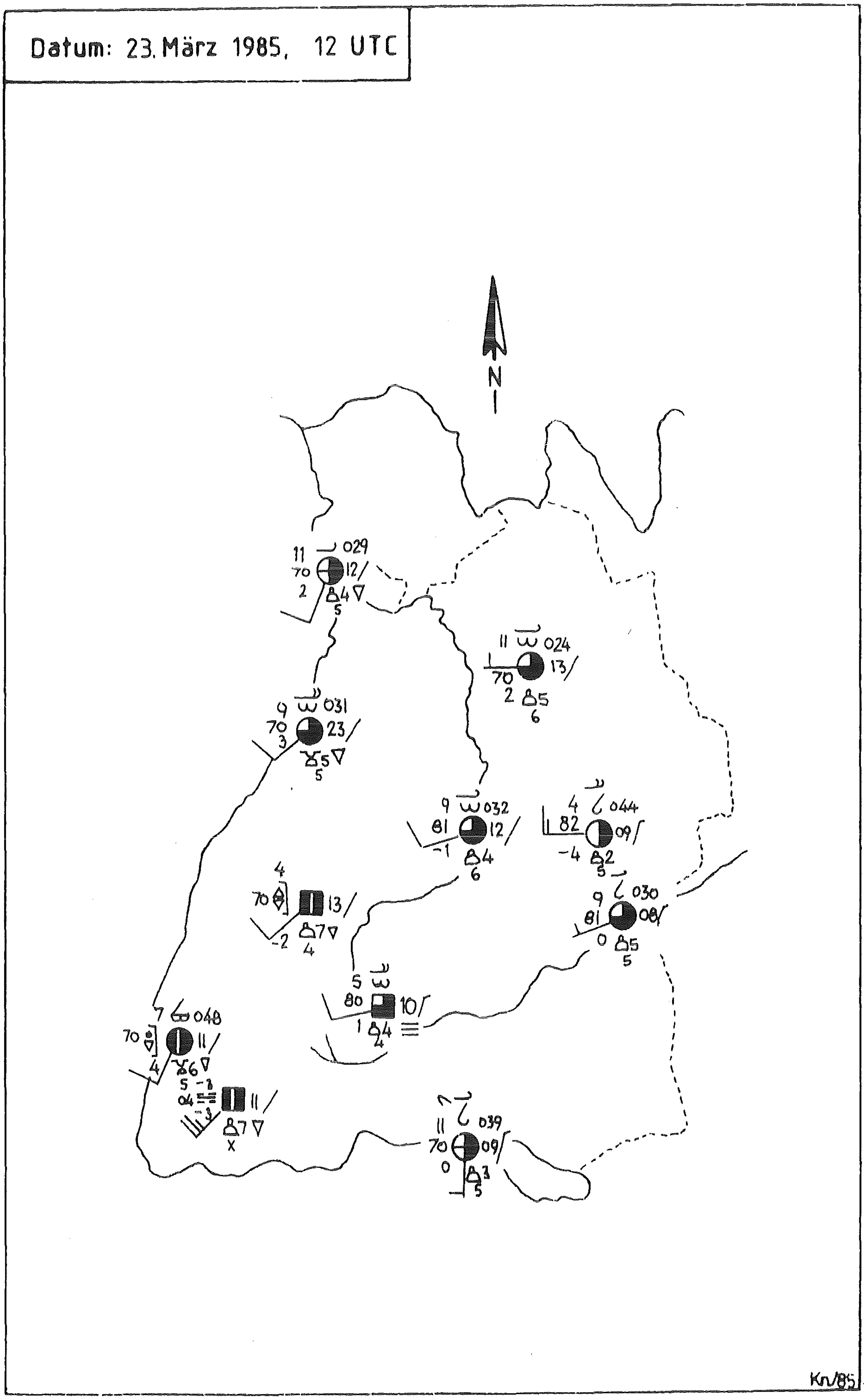


Figure 4/24: Station report in Baden-Württemberg
of 23.3.1985 12 UTC

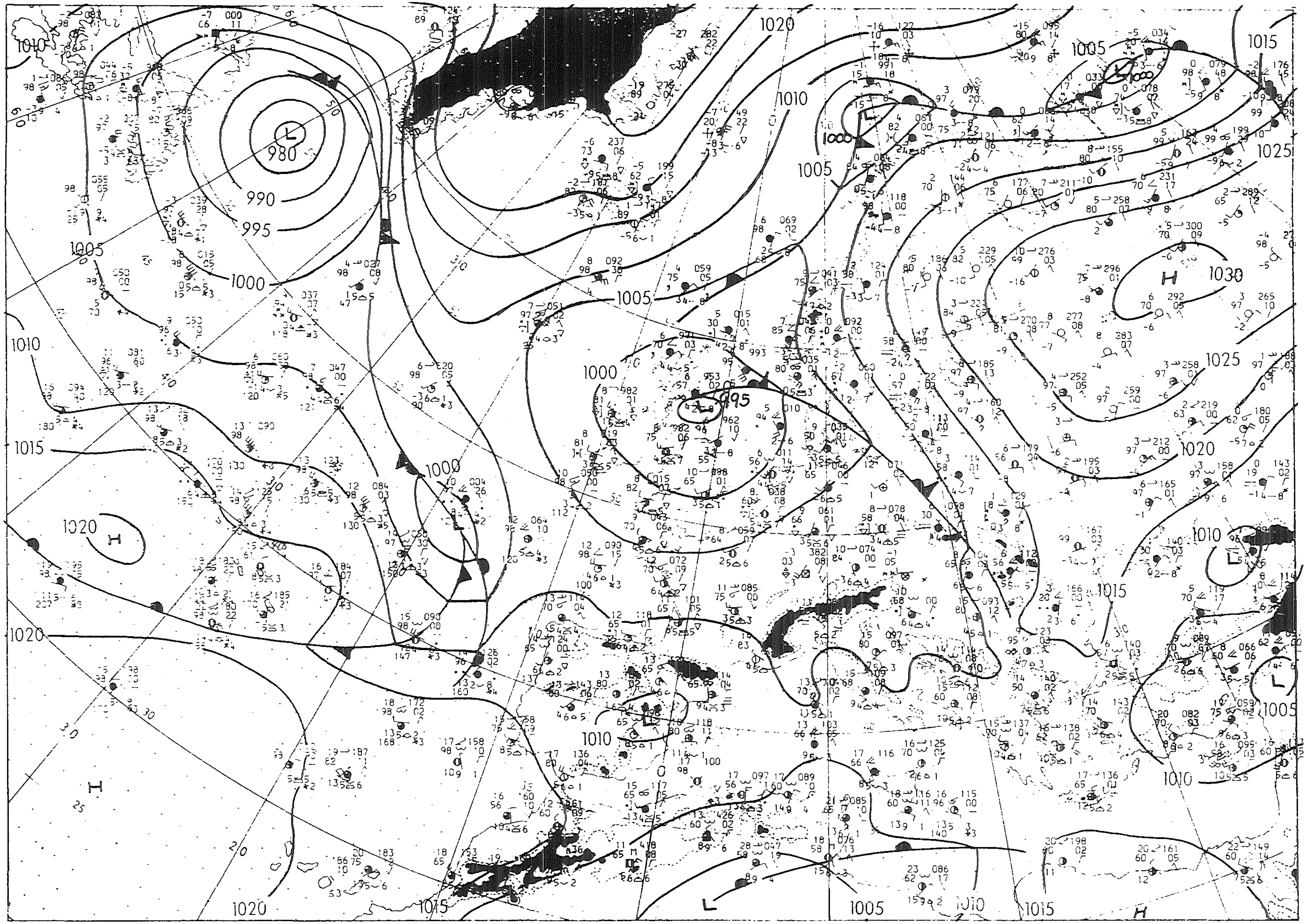


Figure 4/25: Surface chart of 24.3.1985 12 UTC

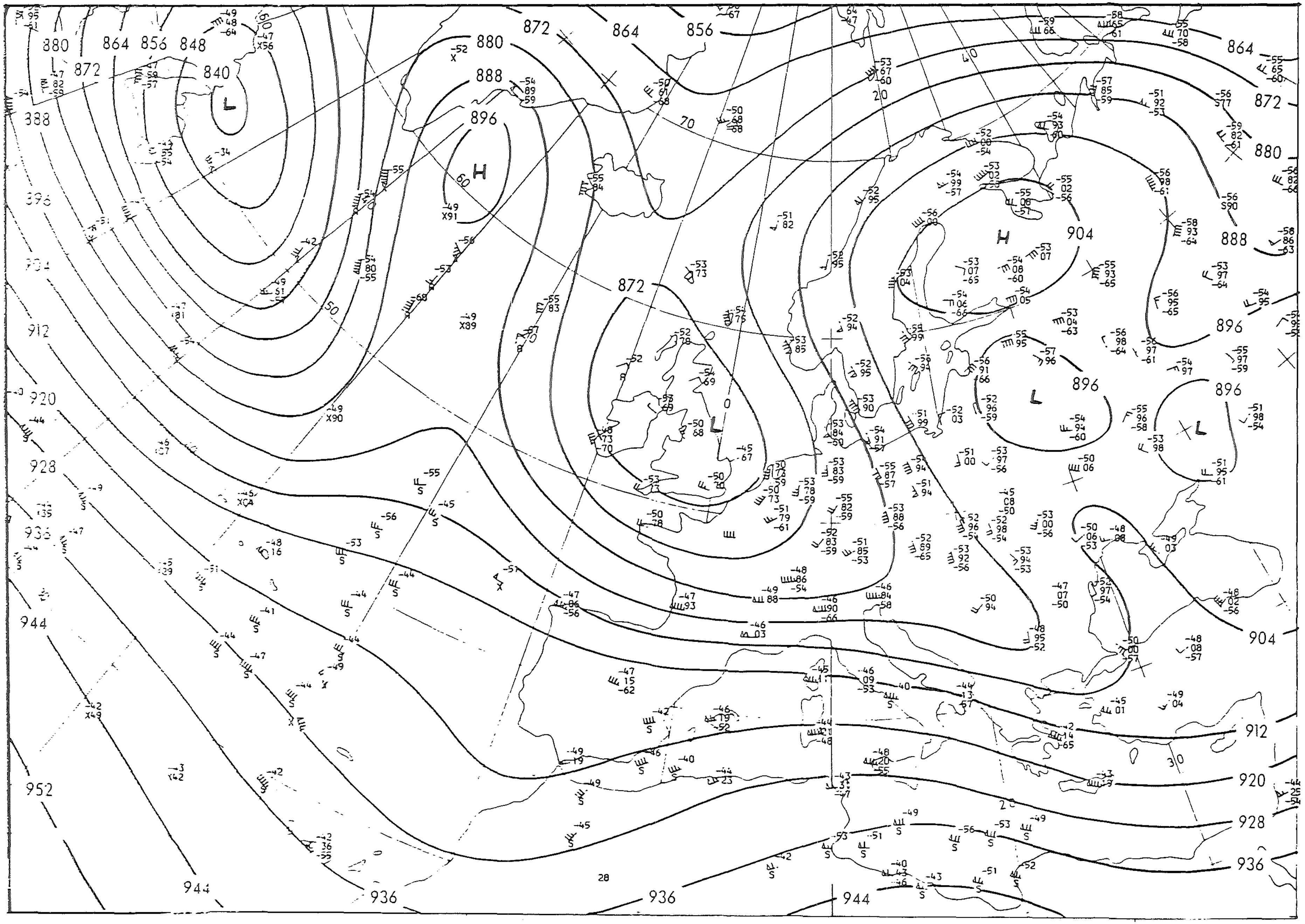


Figure 4/26: Pressure surface 300 hPa of 24.3.1985 00

Datum: 24.März 1985, 18 UTC

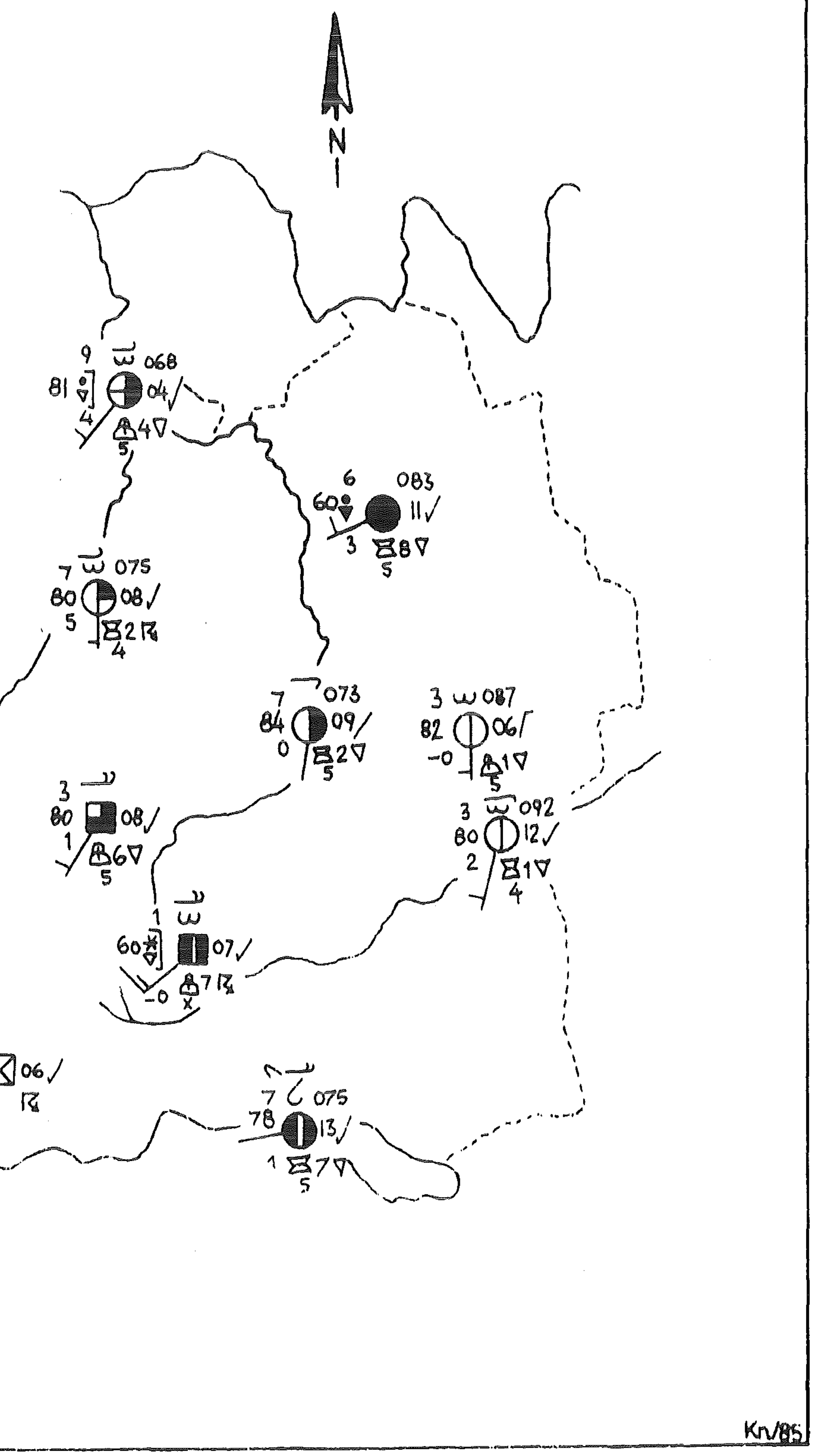
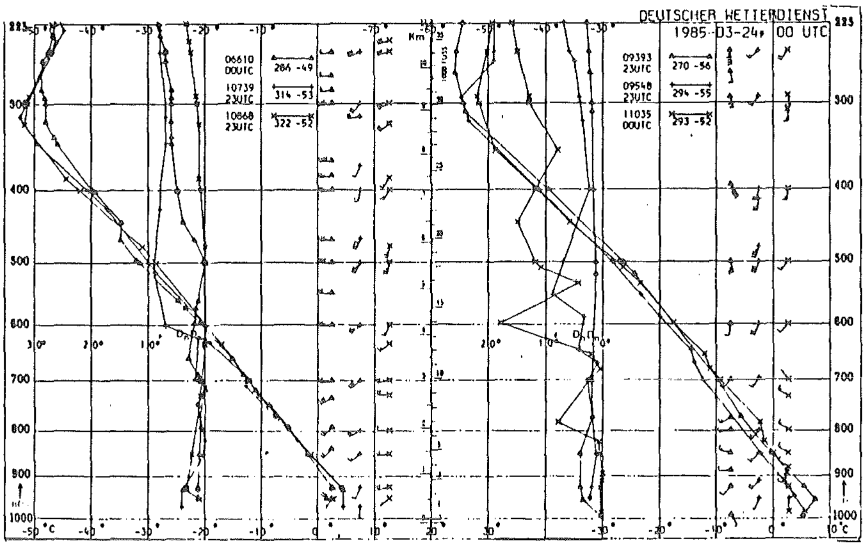


Figure 4/27: Station report in Baden-Württemberg of 24.3.1985 18 UTC



06610 Payerne
09184 Greifswald
09393 Lindenberg
09548 Meiningen
10035 Schleswig
10338 Hannover
10410 Essen
10739 Stuttgart
10868 München-Oberschleißheim
11035 Wien

Figure 4/28: Radio-sonde ascents of 24.3.85 00 UTC

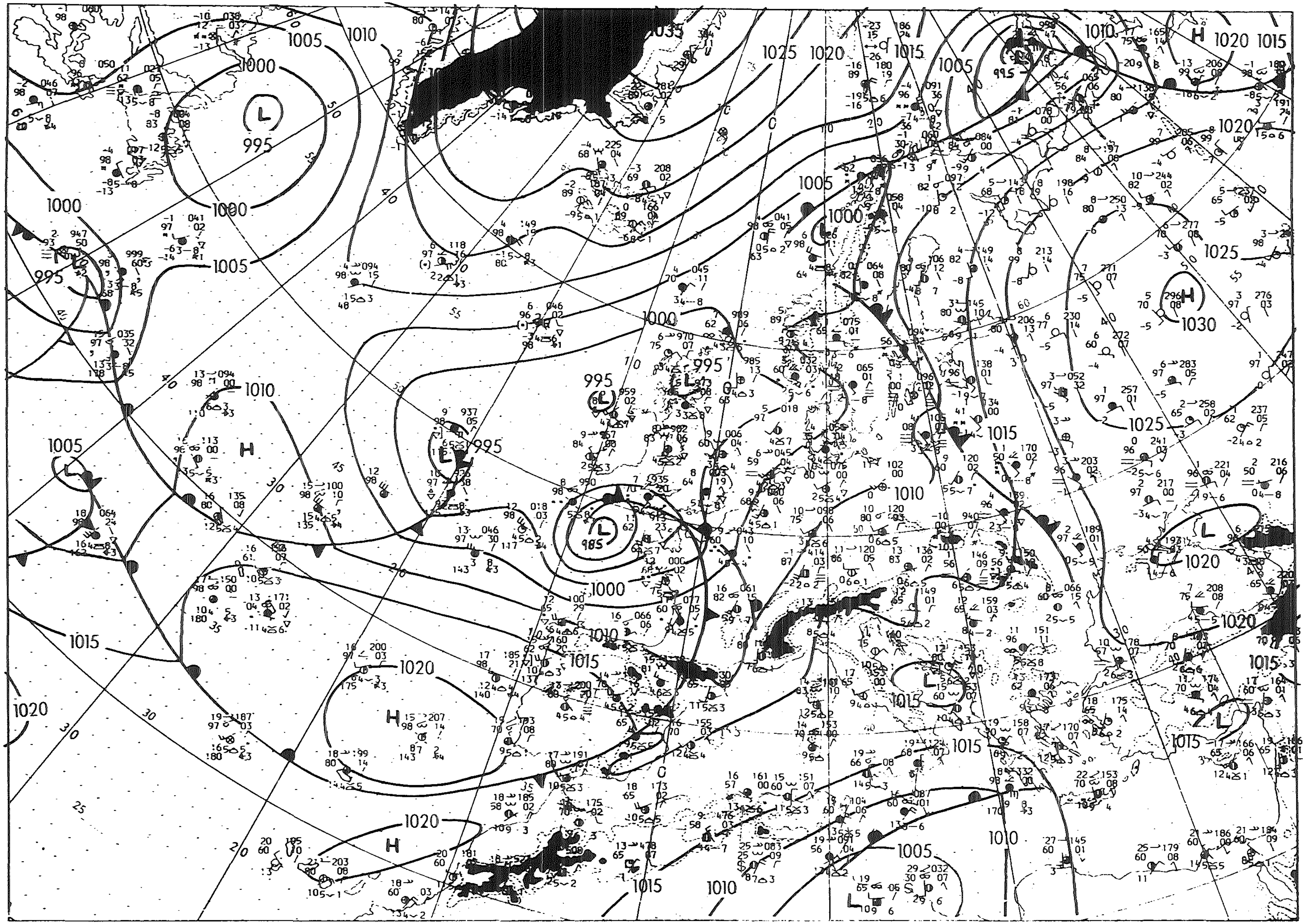


Figure 4/29: Surfache chart of 25.3.1985 12 UTC

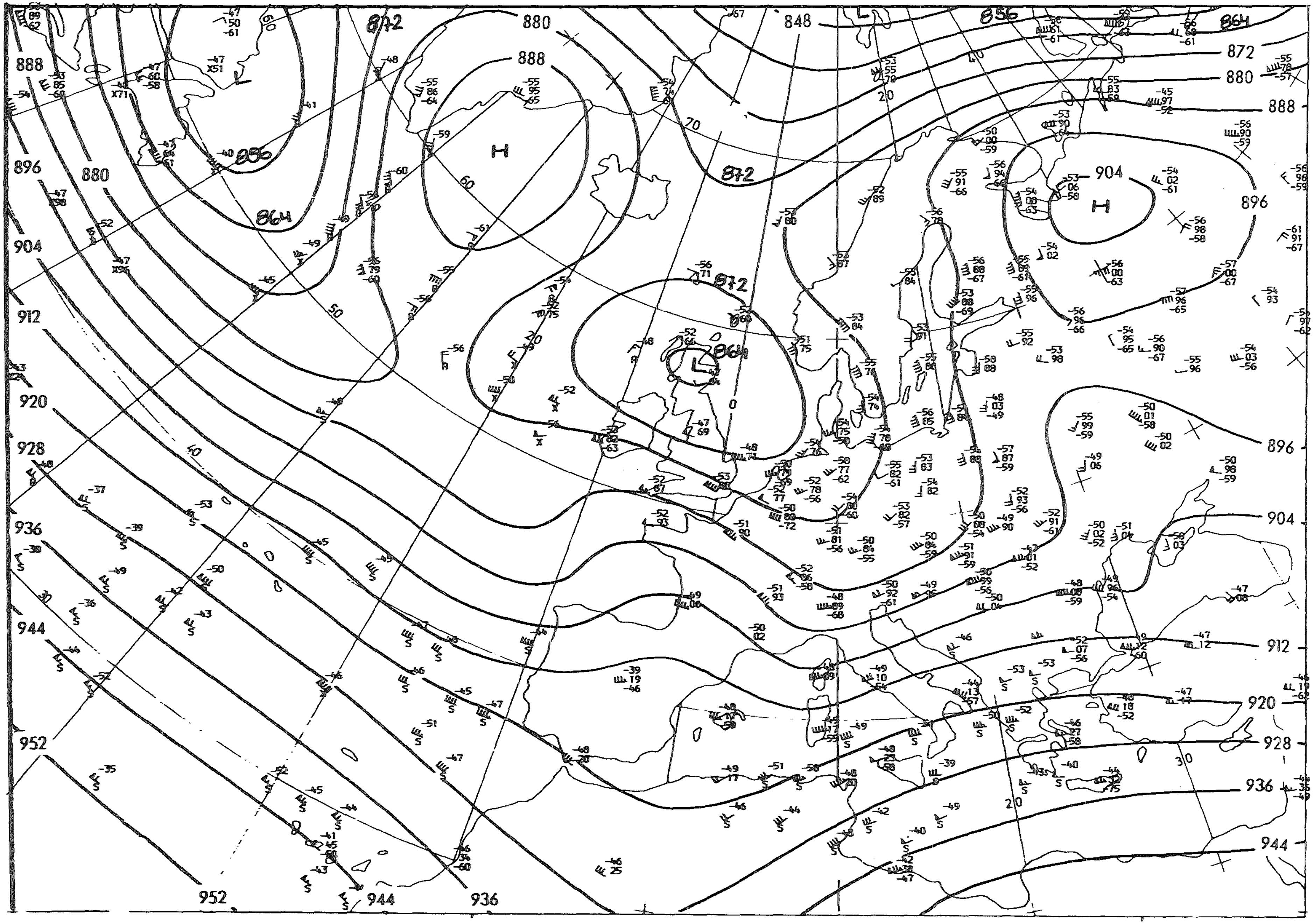


Figure 4/30: Pressure surface 300 hPa of 25.3.1985 00 UTC

Datum: 25.März 1985, 15 UTC

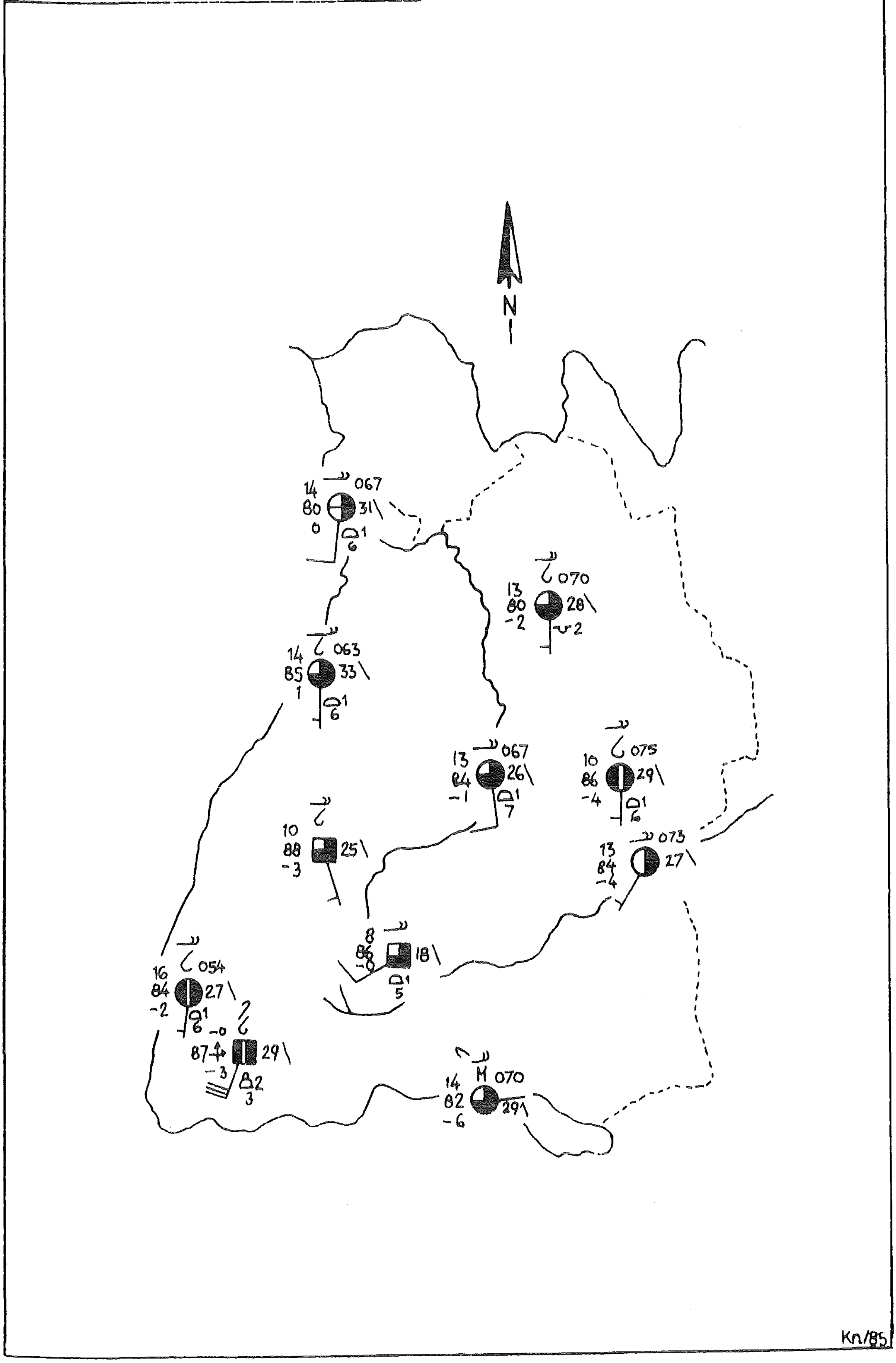


Figure 4/31: Station report in Baden-Württemberg of 25.3.1985 15 UTC

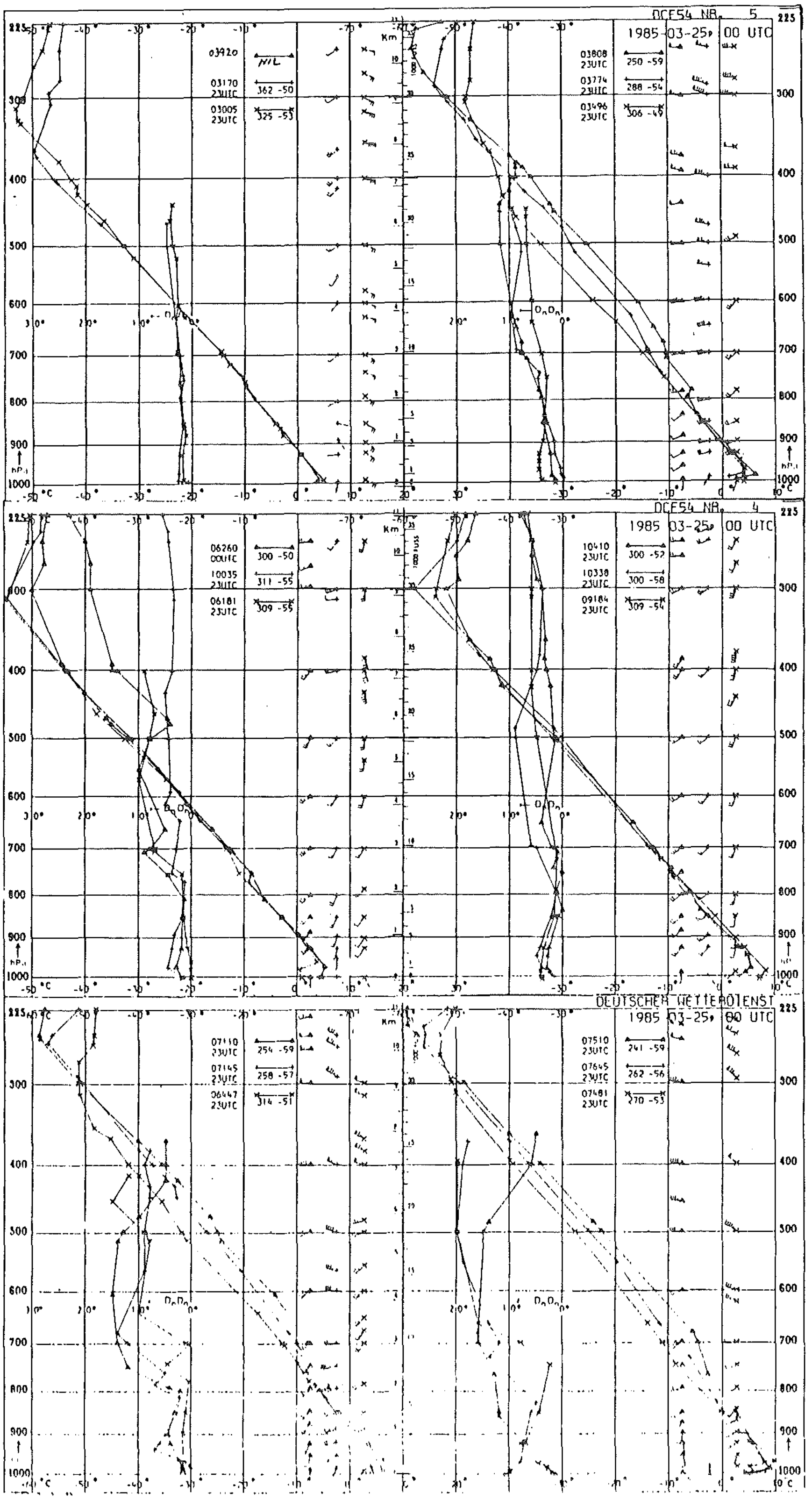


Figure 4/32: Radio-sonde ascents of 25.3.85 00 UTC

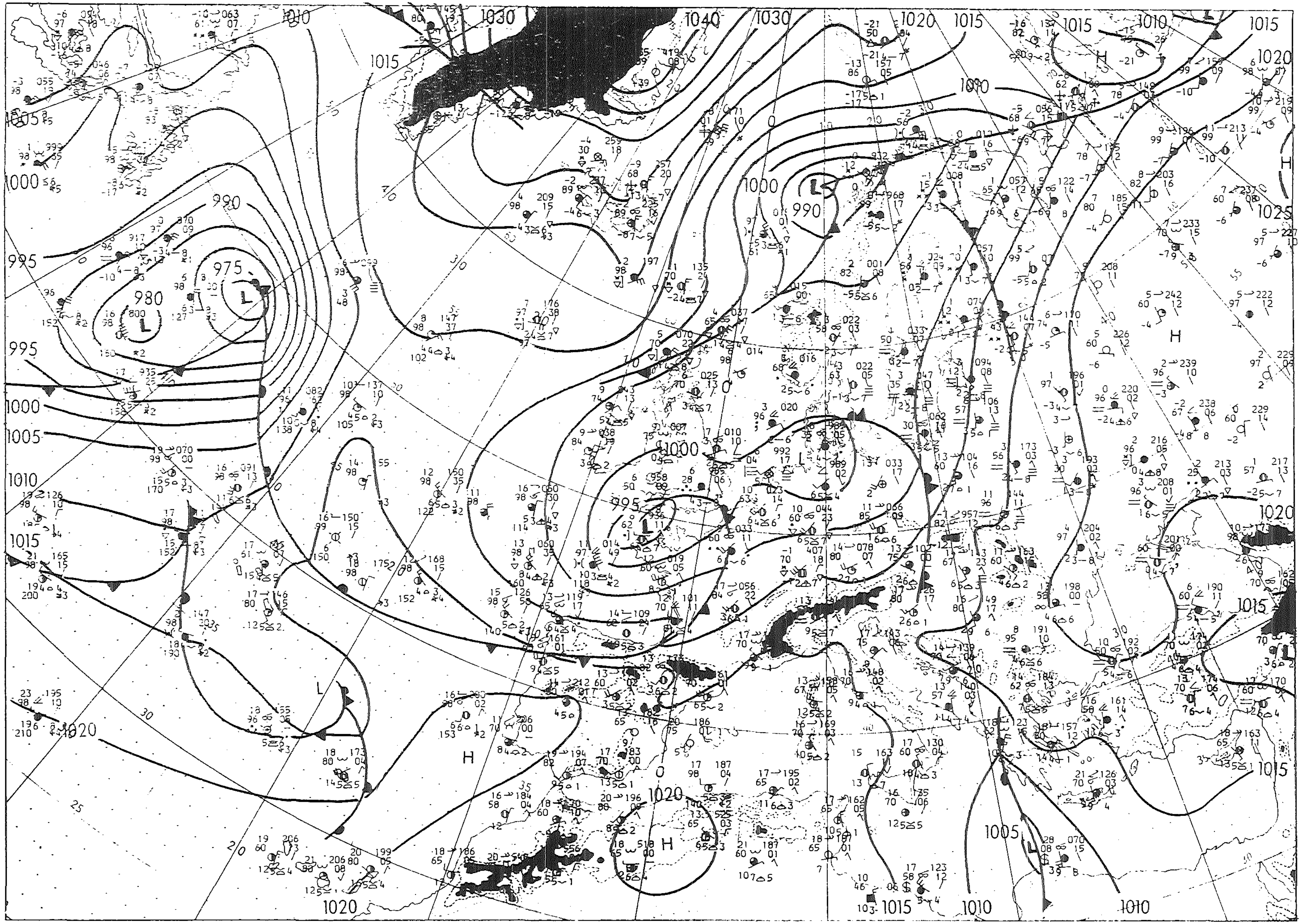


Figure 4/33: Surface chart of 26.3.1985 12 UTC

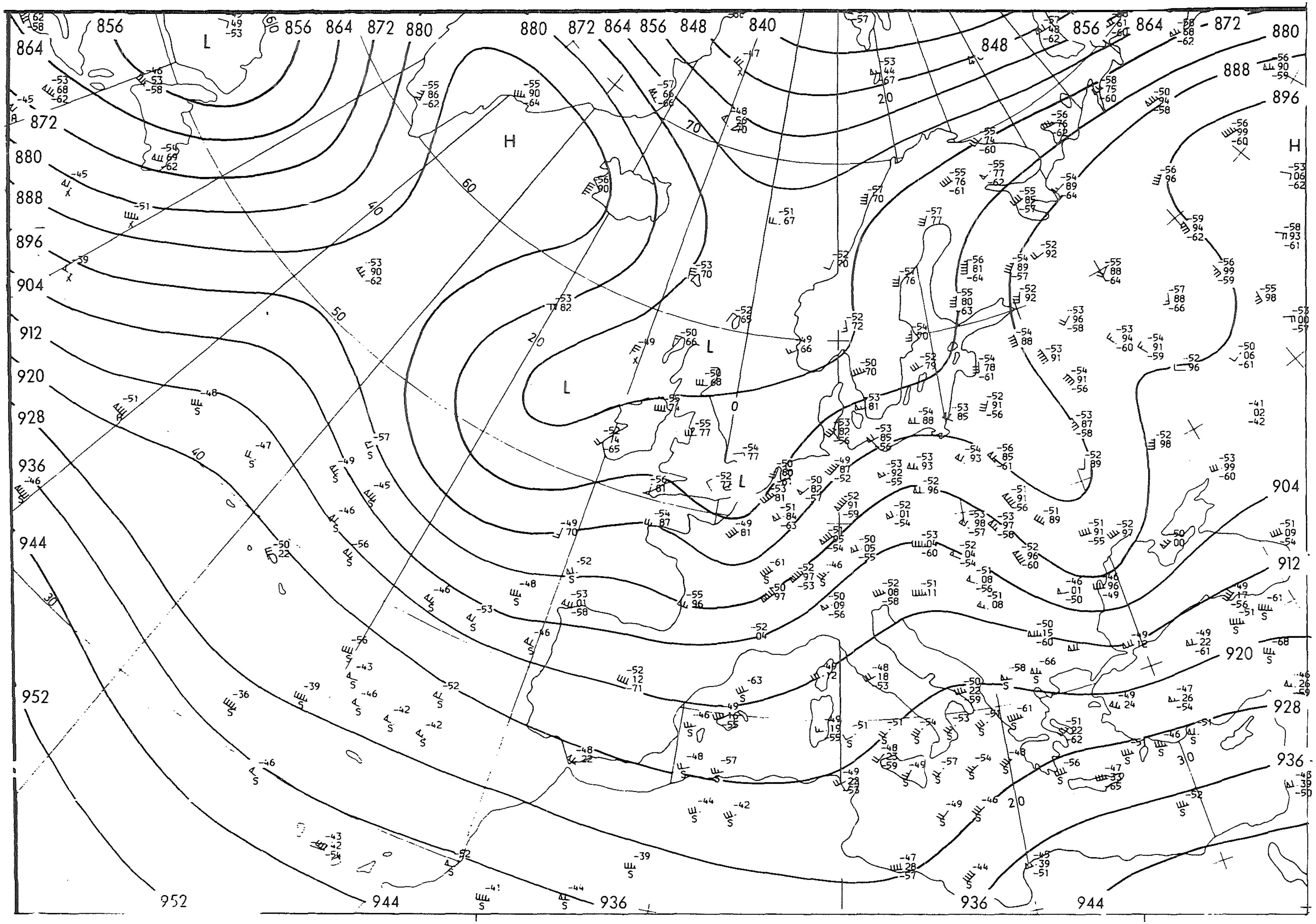


Figure 4/34: Pressure surface 300 hPa of 26.3.1985 00 UTC

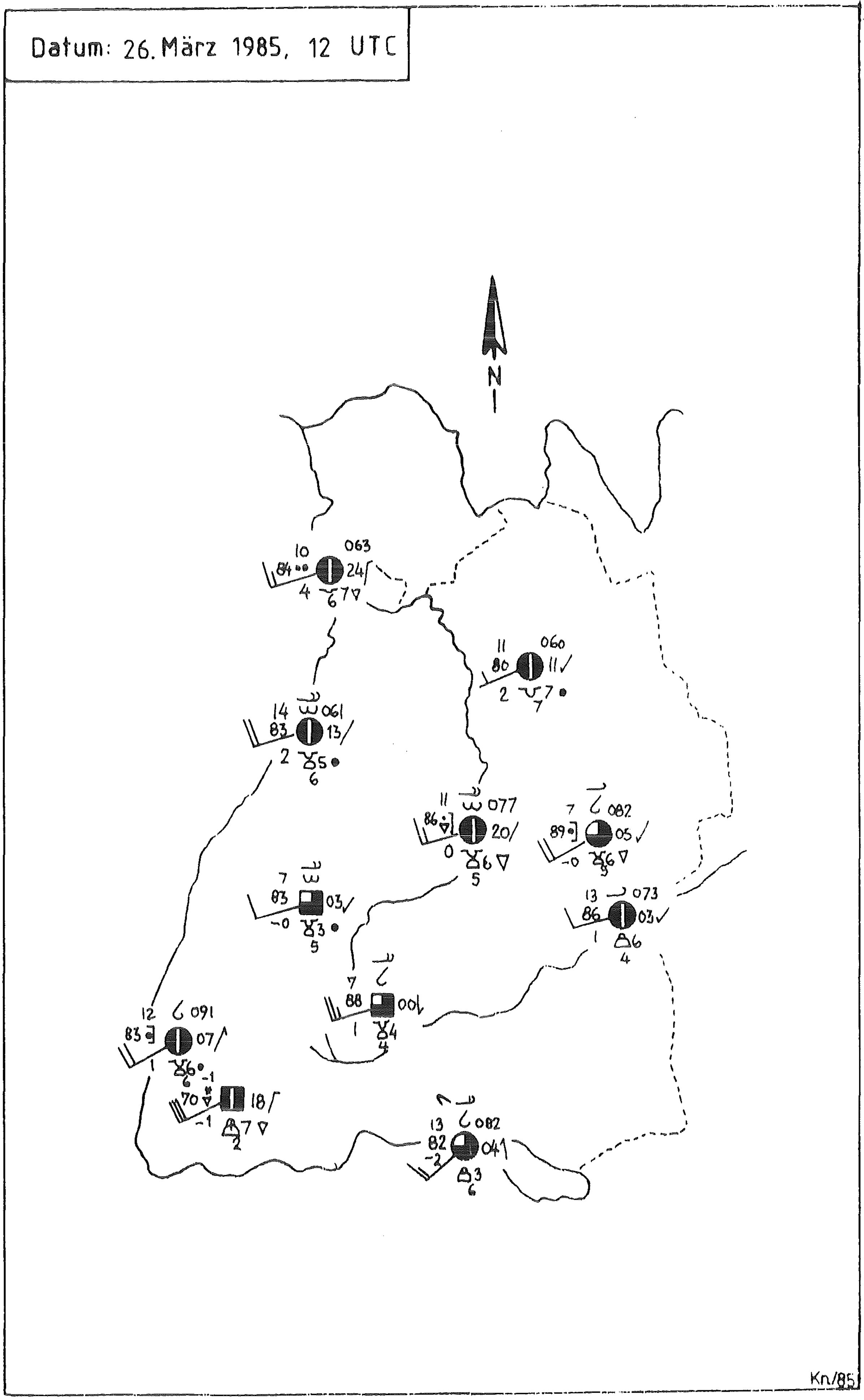


Figure 4/35: Station report in Baden-Württemberg of 26.3.1985 12 UTC

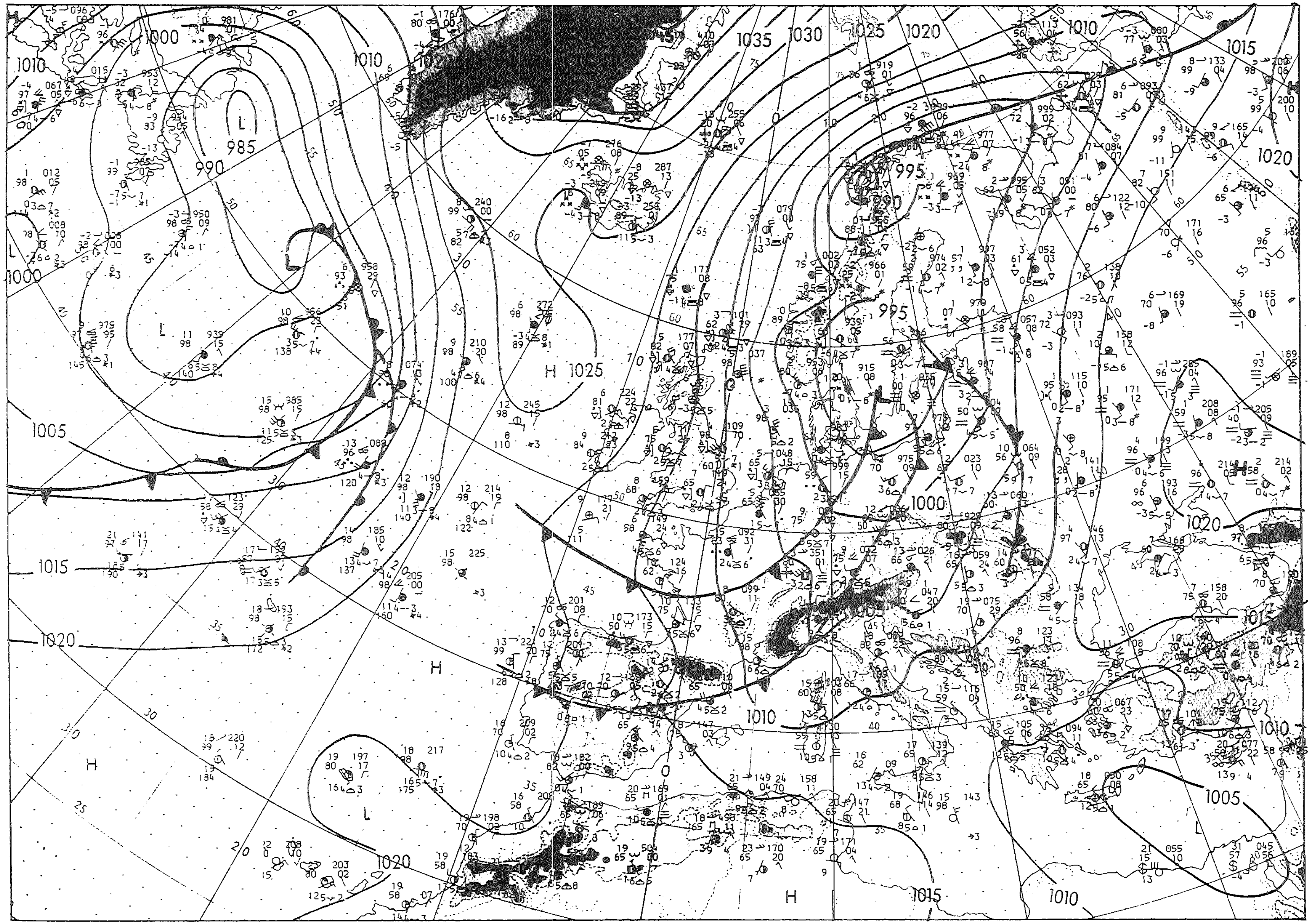


Figure 4/36: Surface chart of 27.3.1985 12 UTC

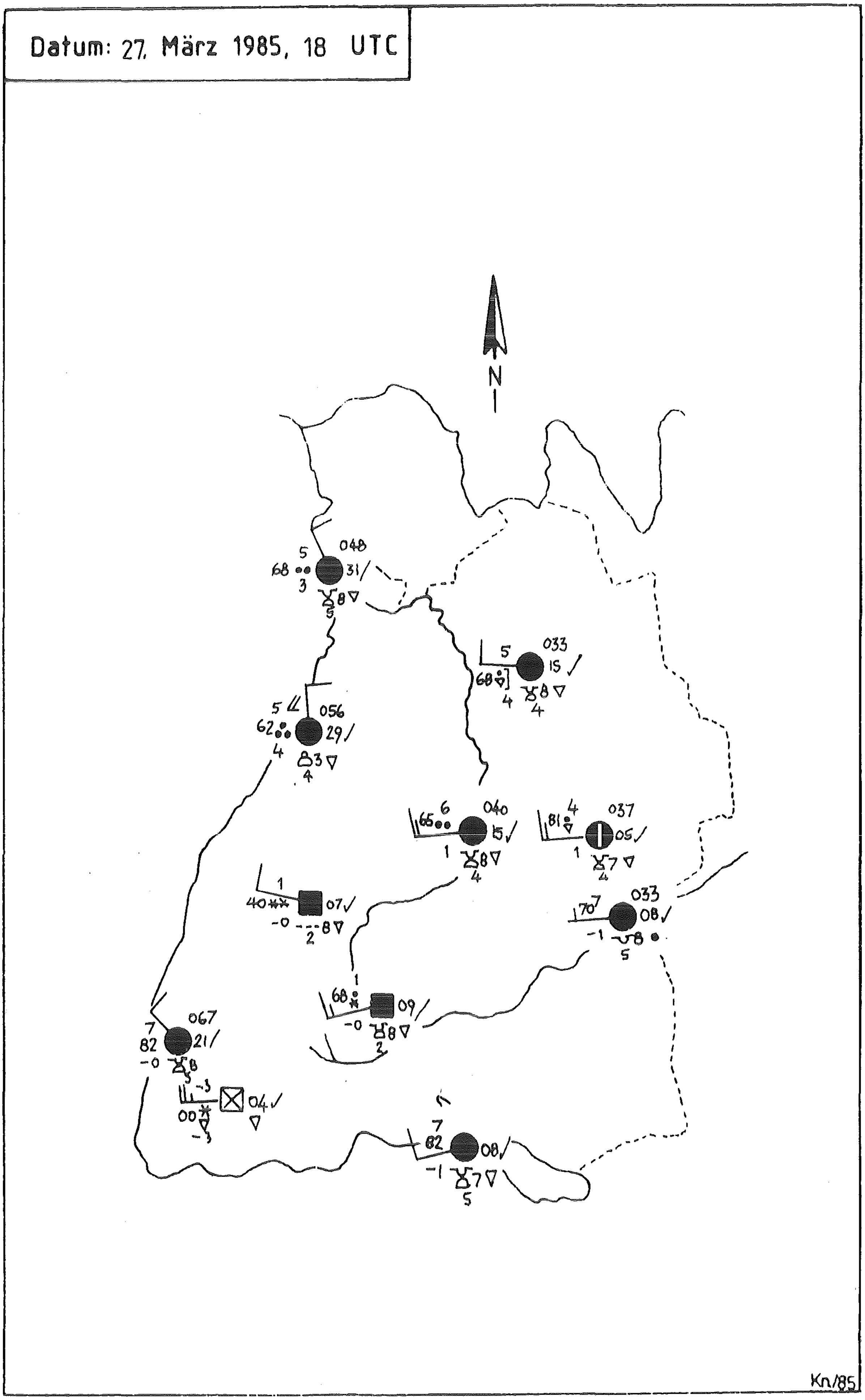


Figure 4/37: Station report in Baden-Württemberg of 27.3.1985 18 UTC

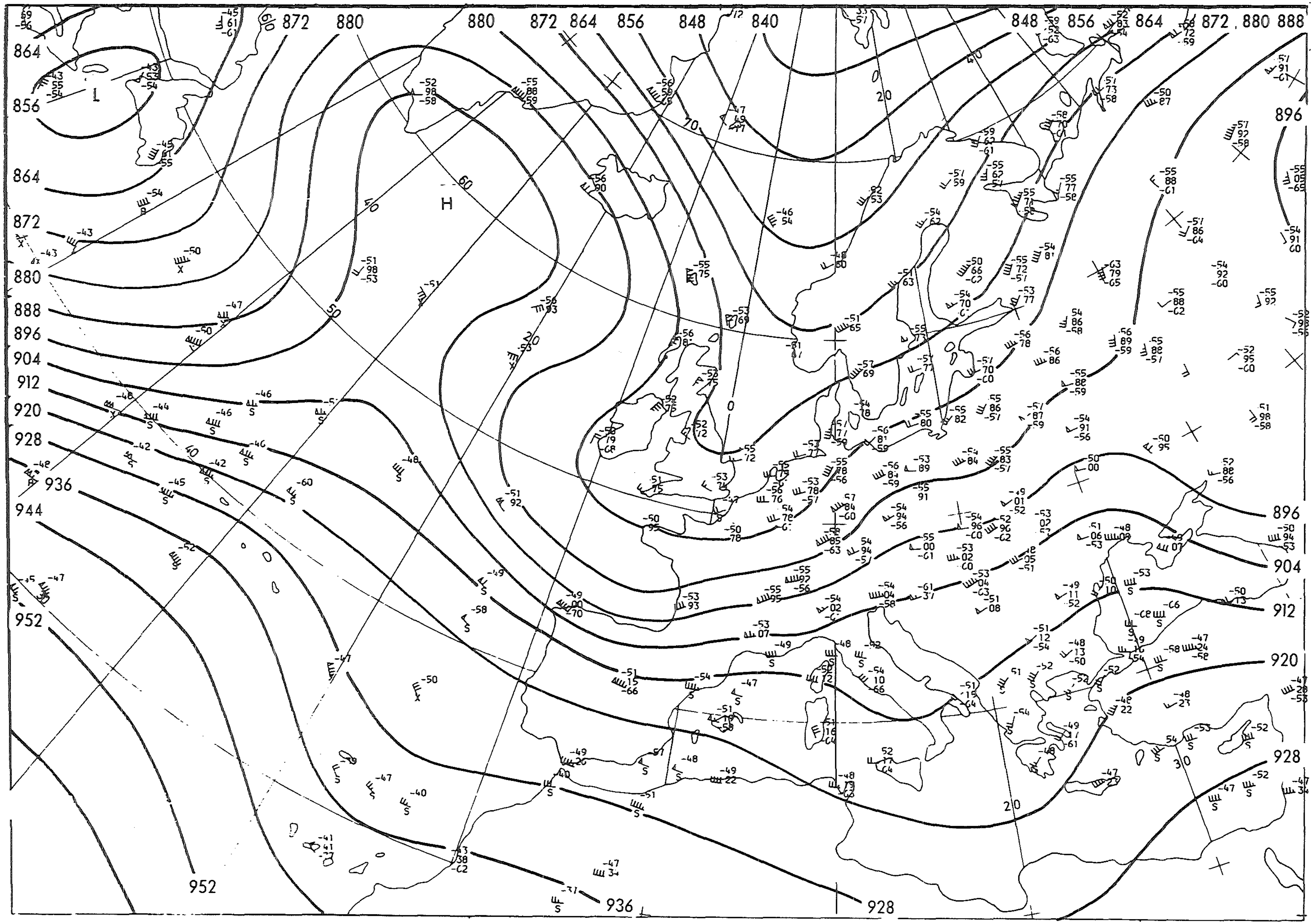


Figure 4/38: Pressure surface 300 hPa of 27.3.1985 00 UTC

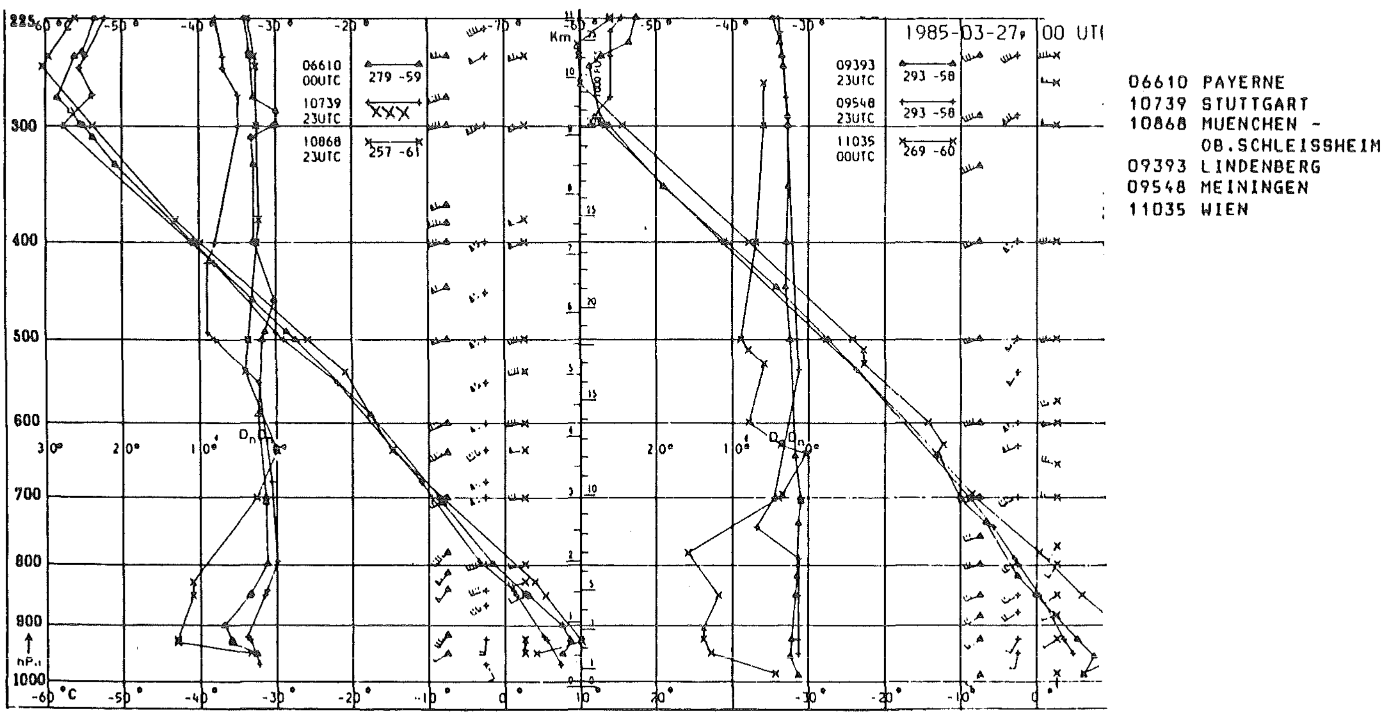


Figure 4/39: Radio-sonde ascents of 27.3.85 00 UTC

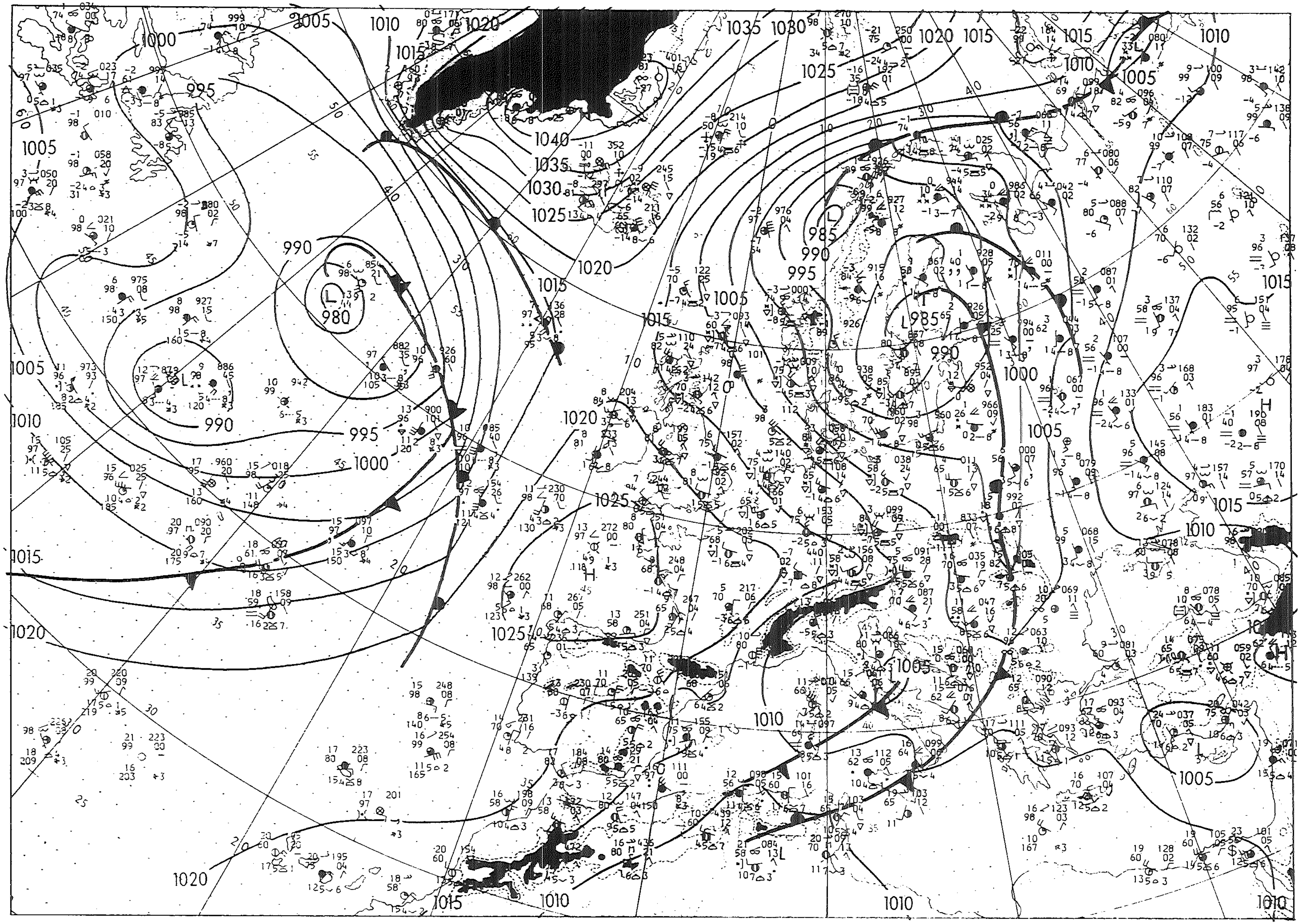


Figure 4/40: Surface chart of 28.3.1985 12 UTC

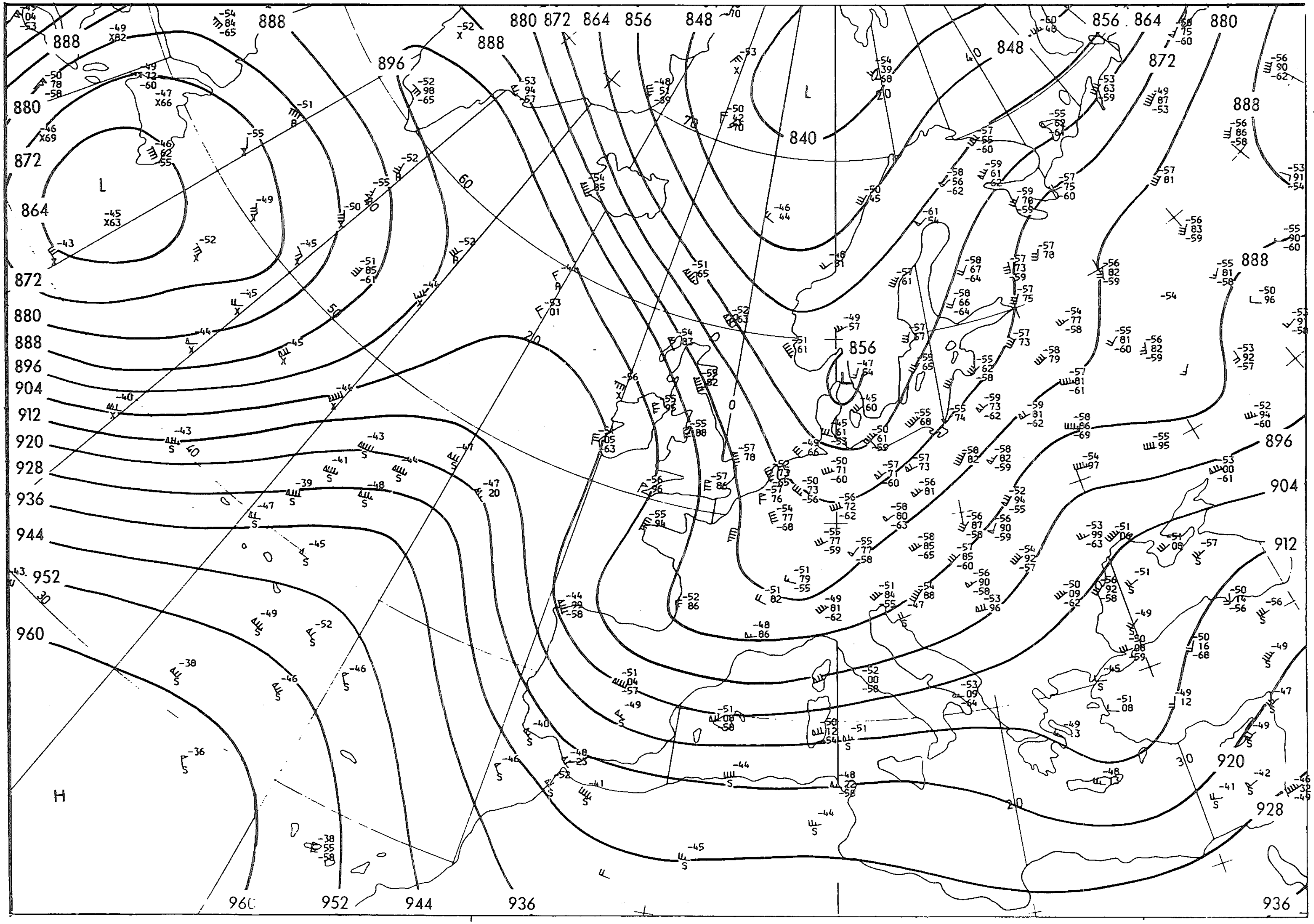


Figure 4/41: Pressure surface 300 hPa of 28.3.1985 00 UTC

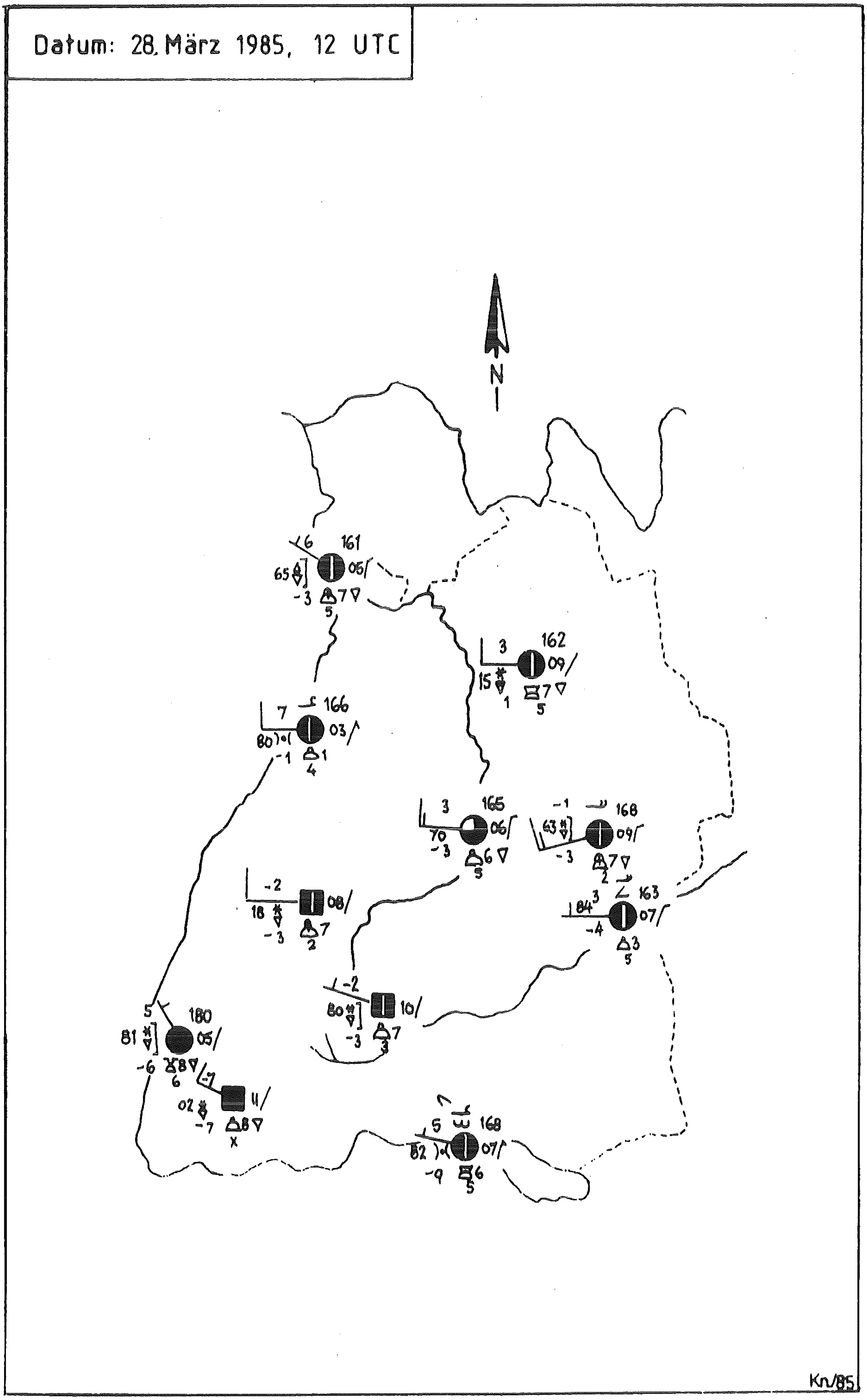


Figure 4/42: Station report in Baden-Württemberg
ldung 4/42: Sc.. of 28.3.1985 12 UTC

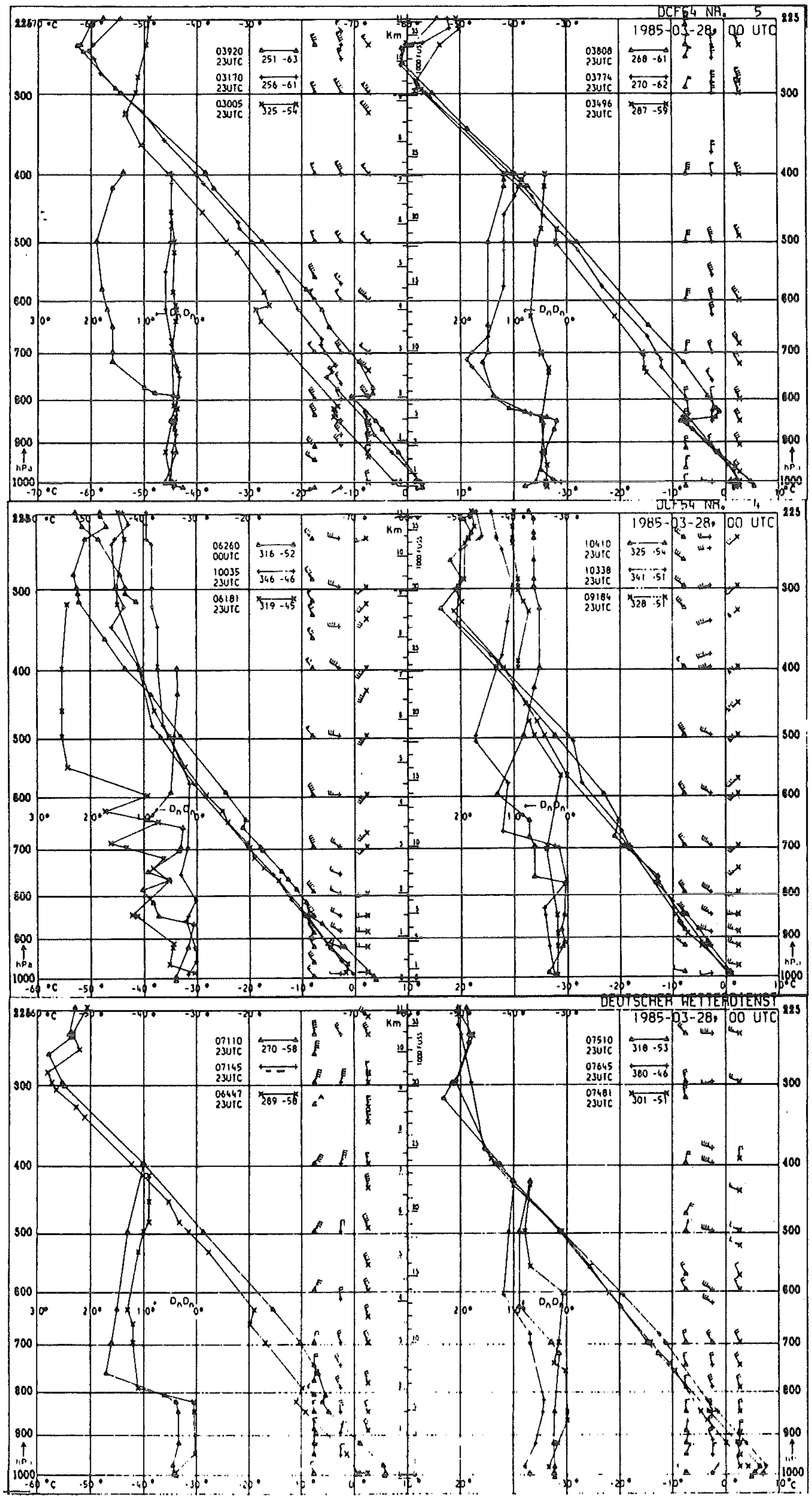


Figure 4/43: Radio-sonde ascents of 28.3.85 00 UTC

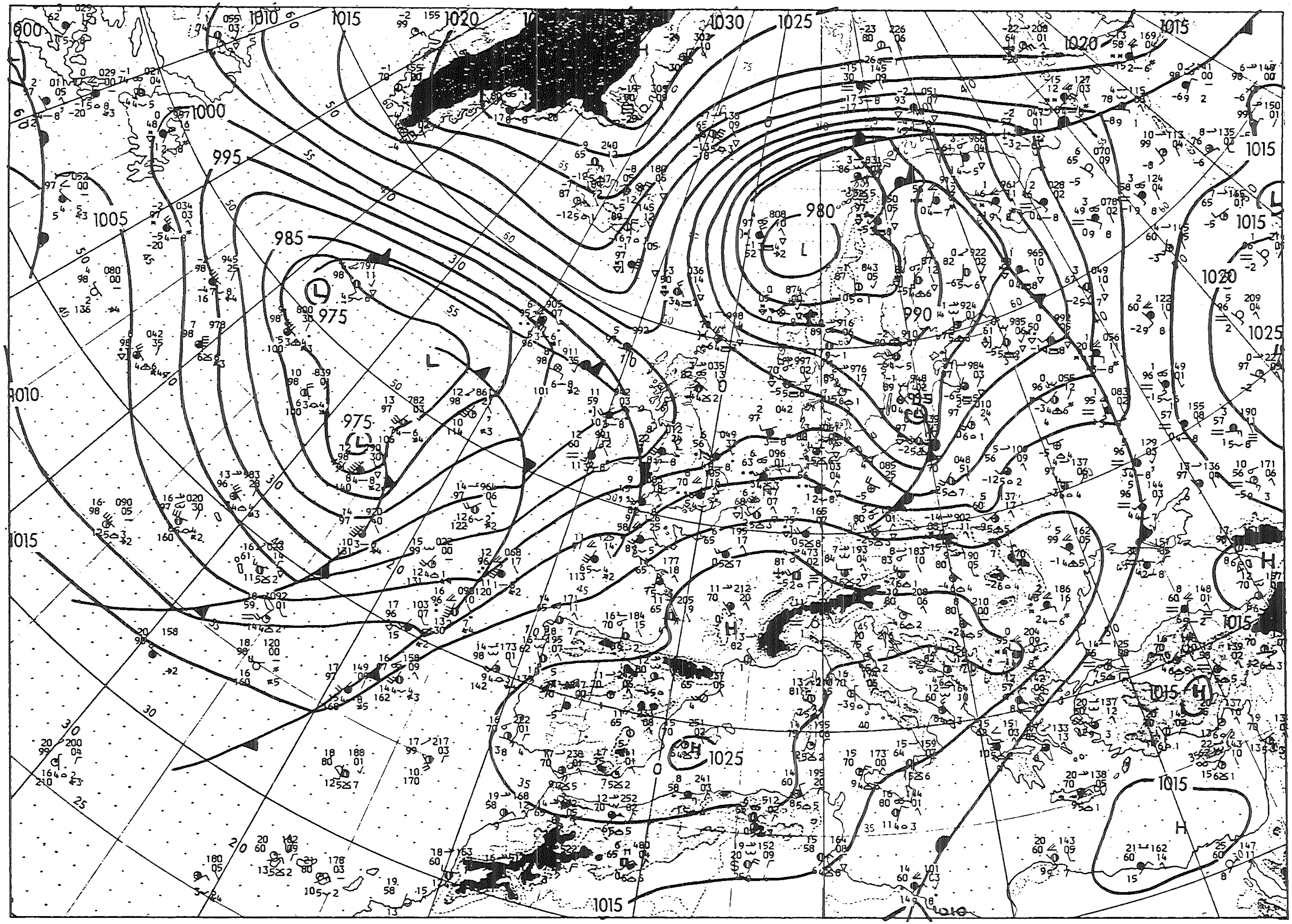


Figure 4/44: Surface chart of 29.3.1985 12 UTC

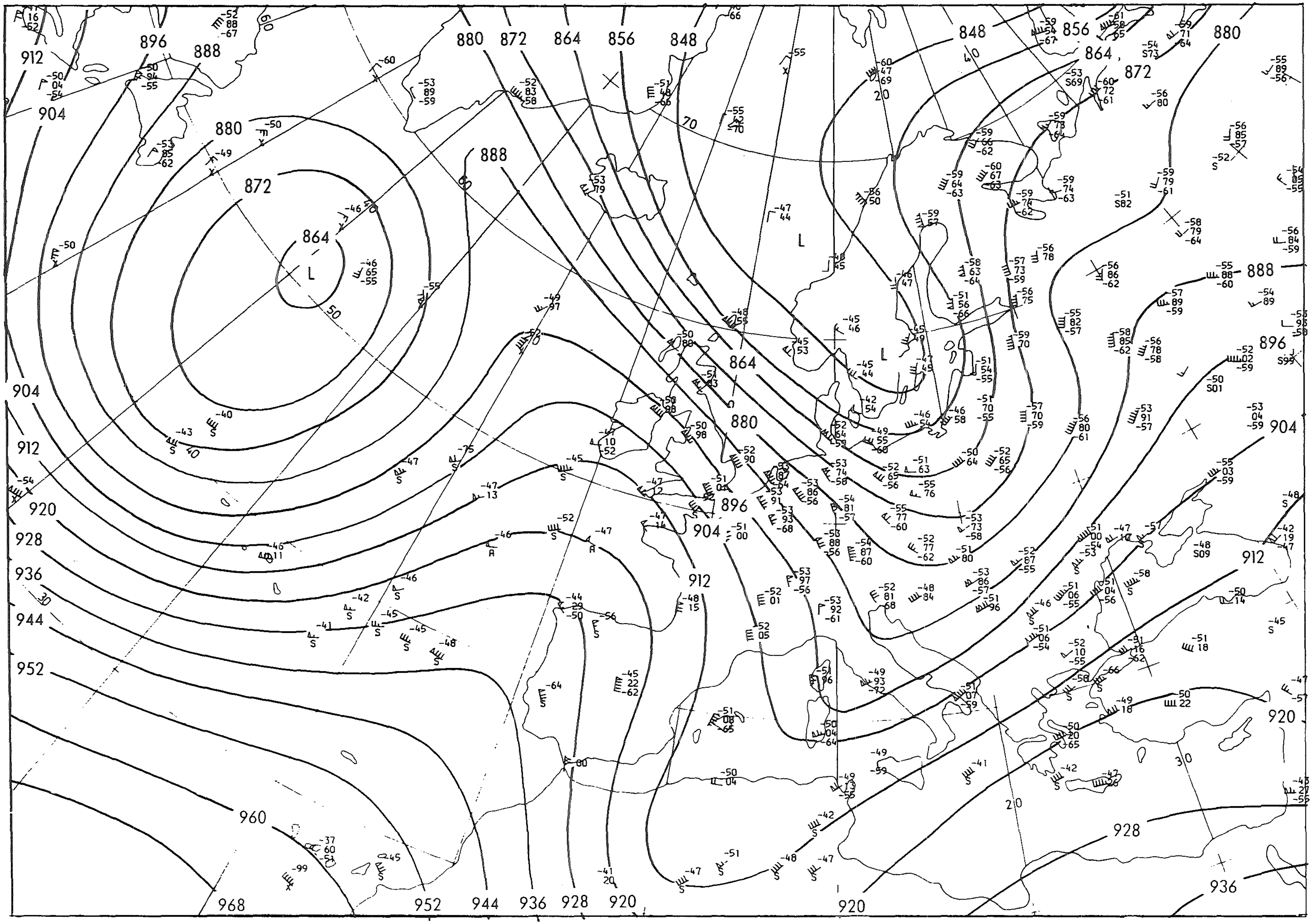


Figure 4/45: Pressure surface 300 hPa of 29.3.1985 00 UTC

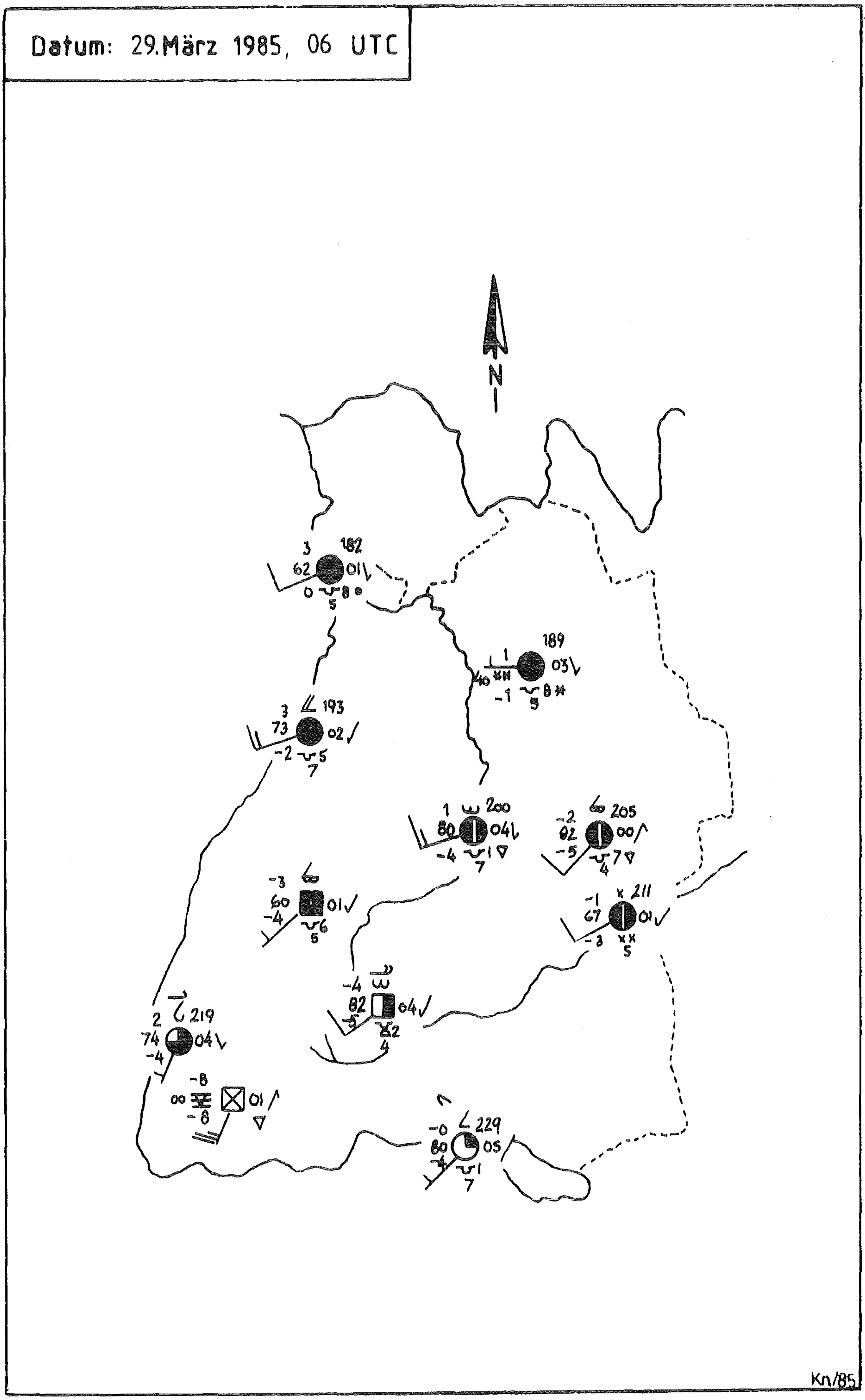


Figure 4/46: Station report in Baden-Württemberg
of 29.3.1985 06 UTC

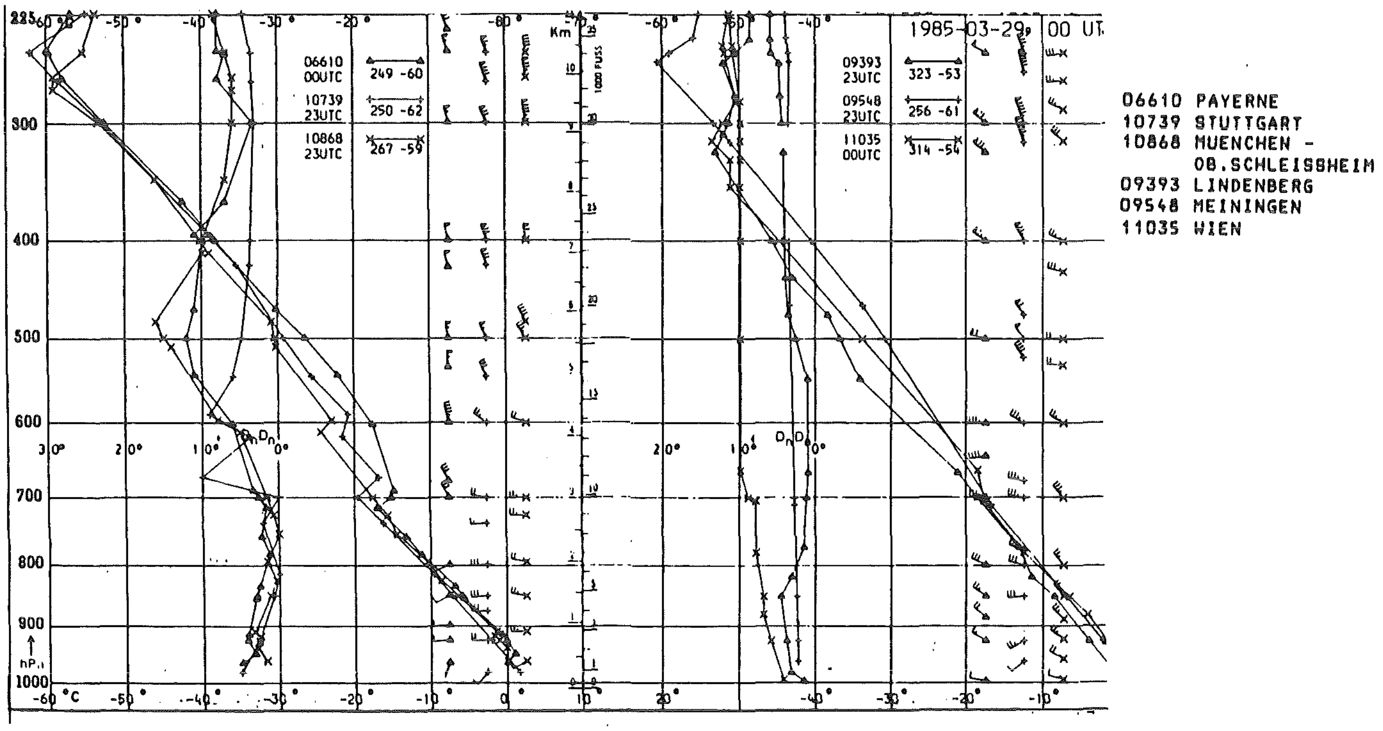


Figure 4/47: Radio-sonde ascents of 29.3.85 00 UTC

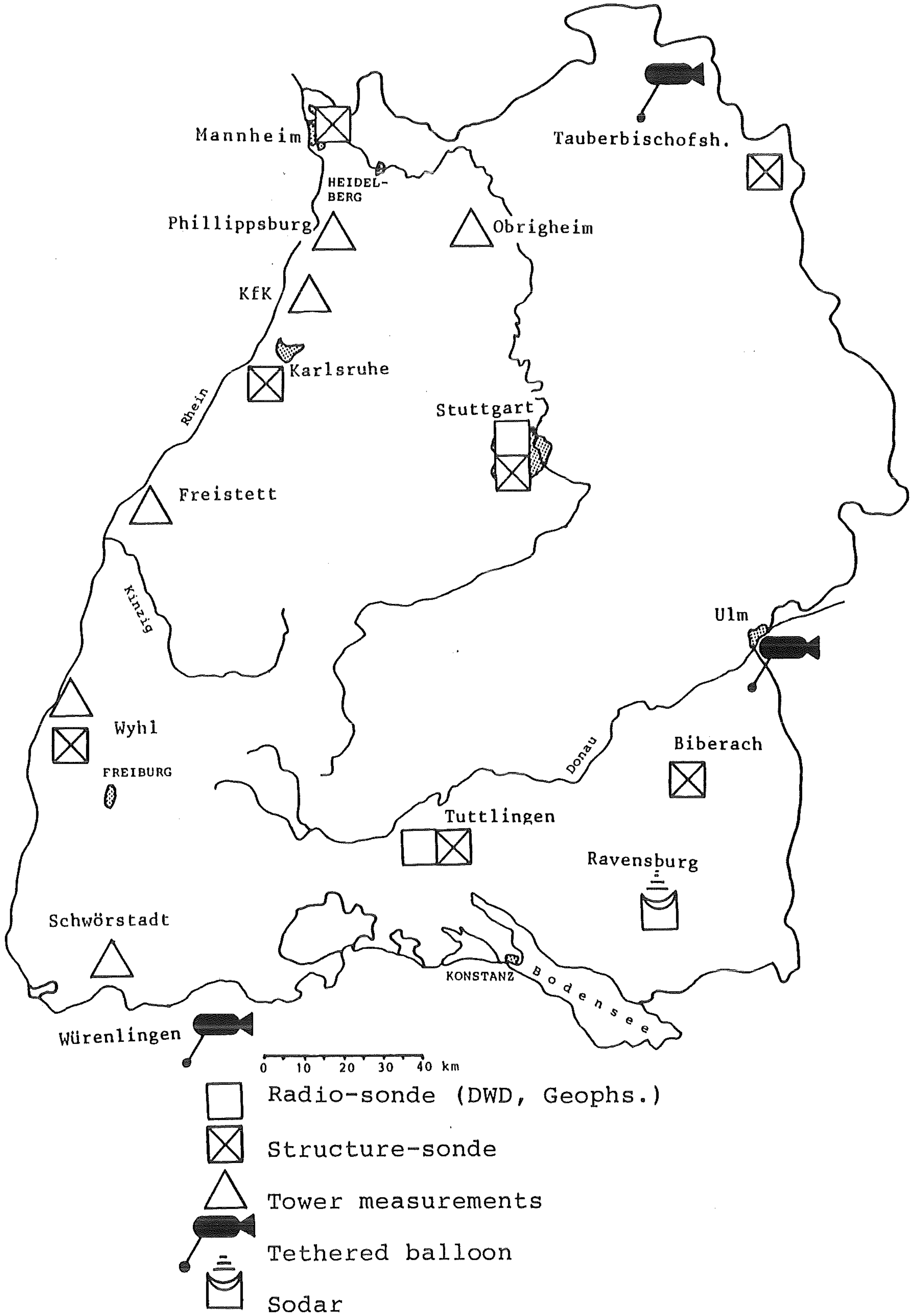


Figure 6/1: Position of vertical sounding systems

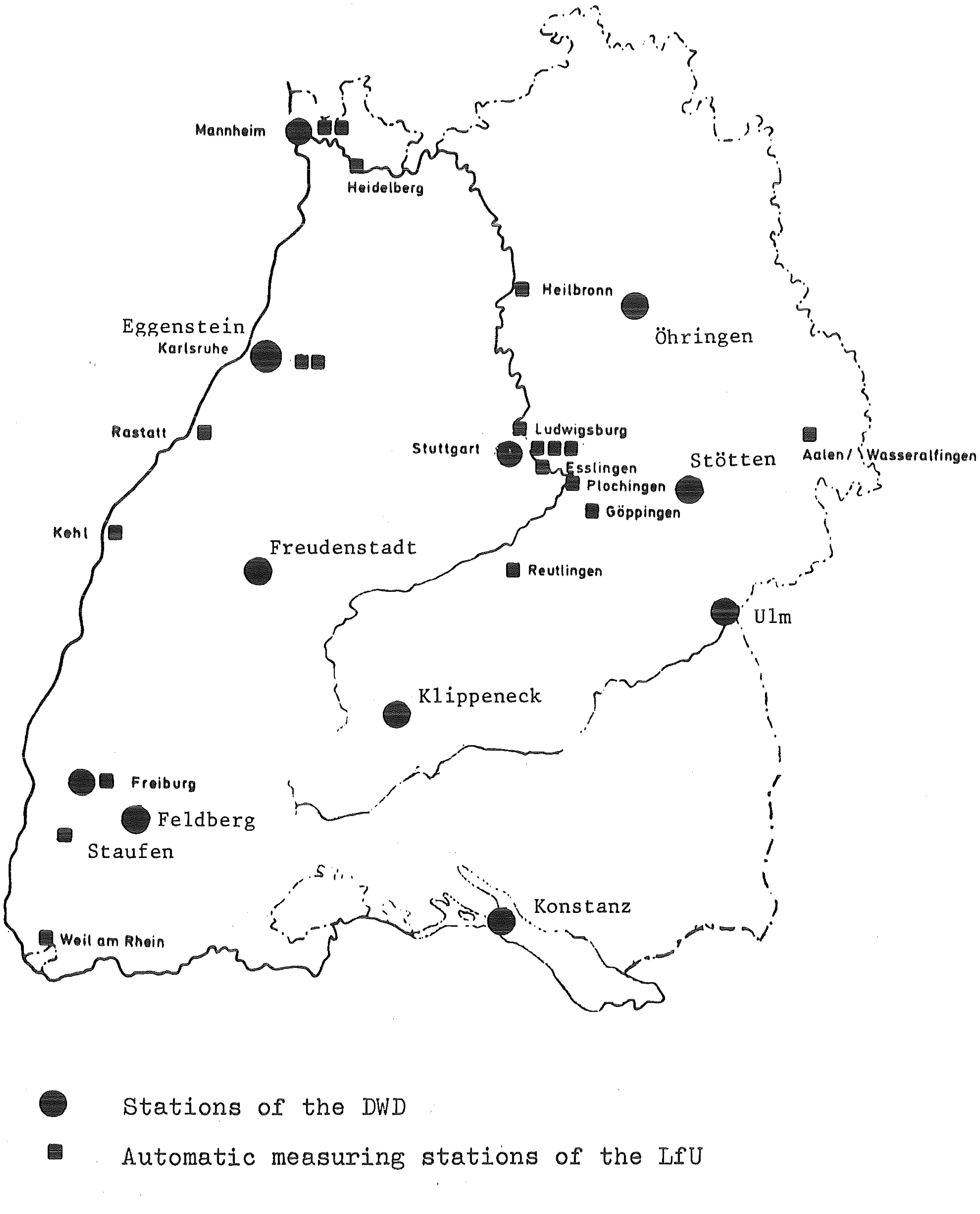


Figure 6/2: Surface meteorological stations

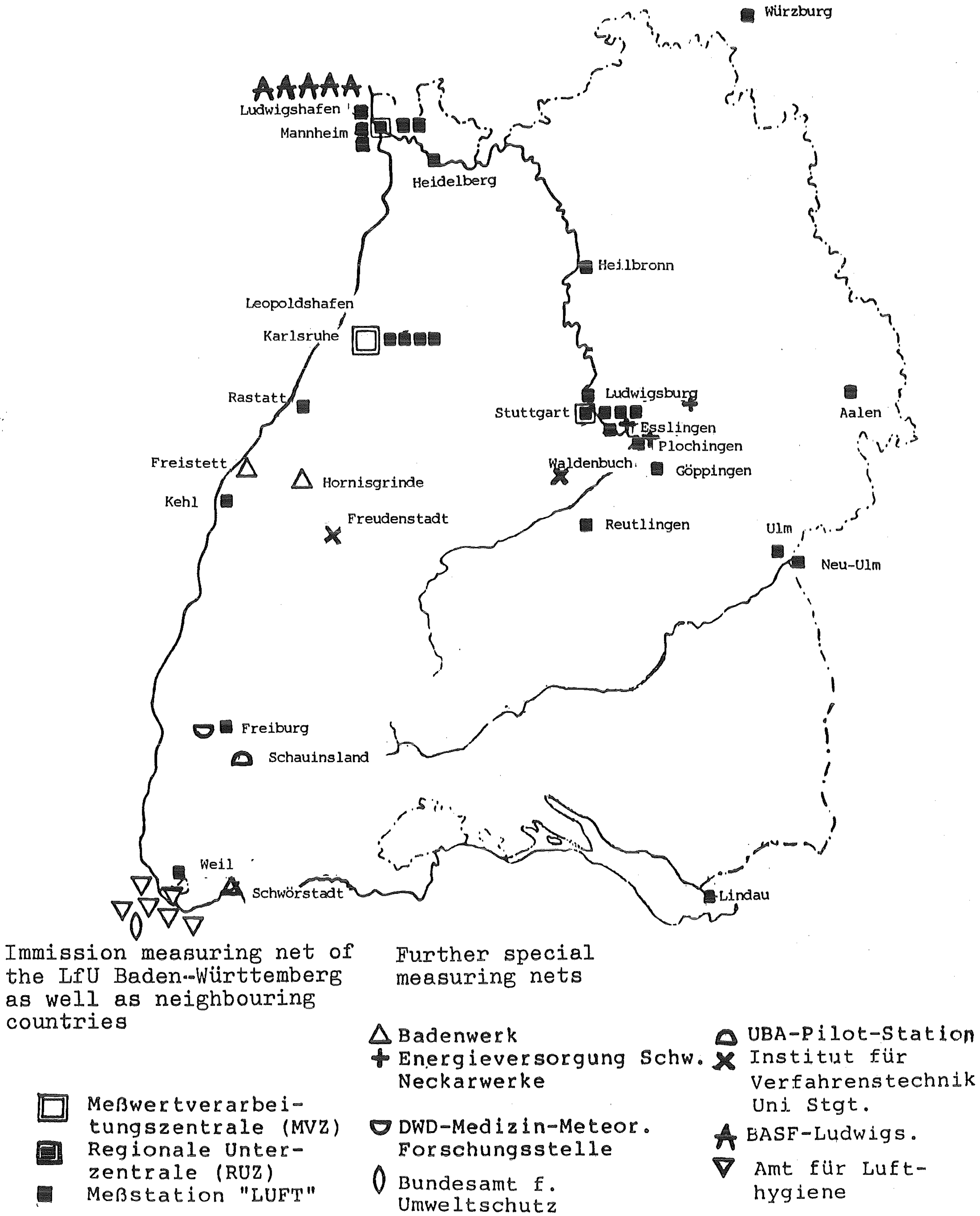


Figure 8/1: Immission measuring networks - continuously in action-as well as special-measuring networks

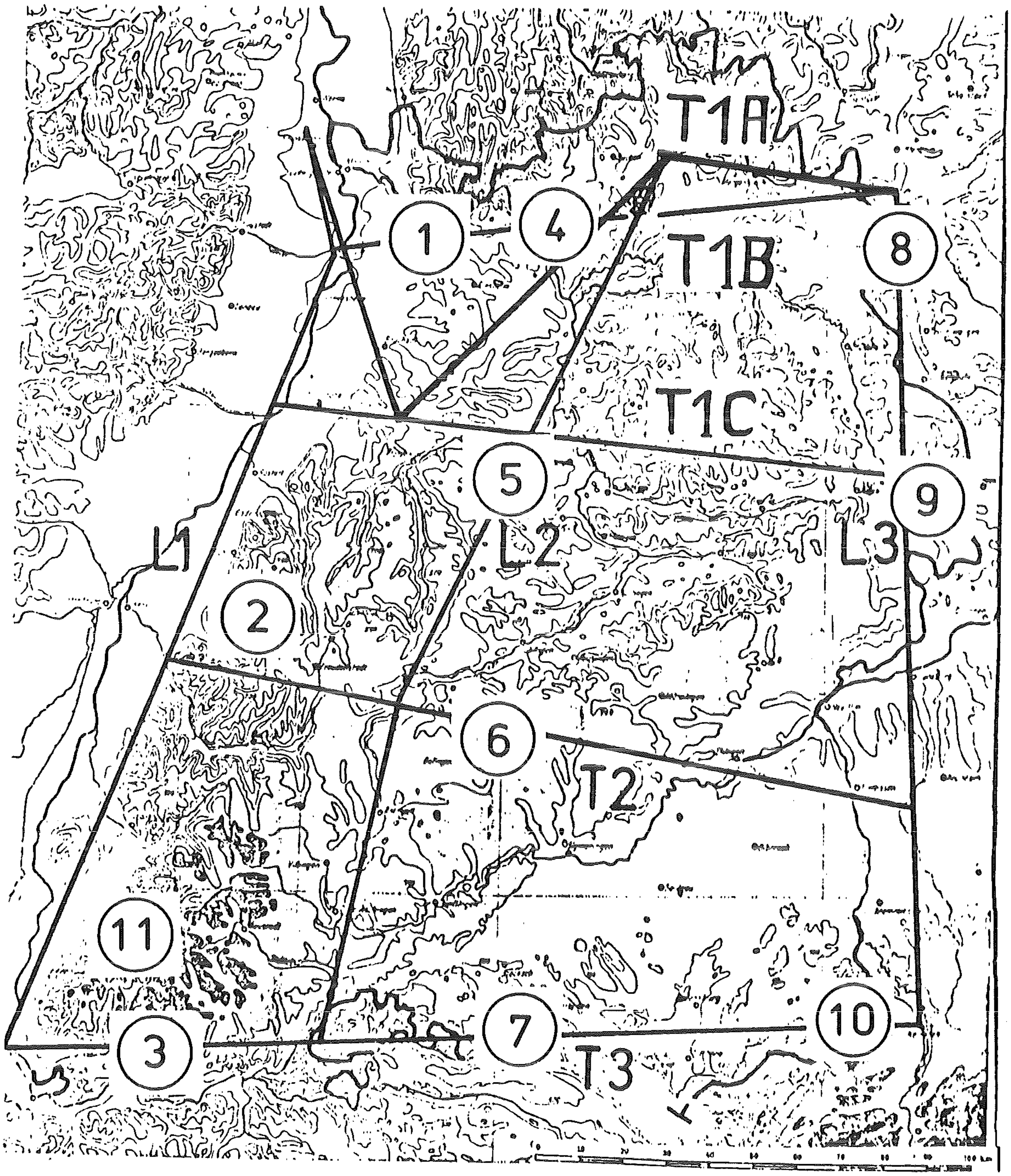


Figure 8/2: Measuring stations for SO_2 and particle bound pollutants

1	Königstuhl, Bergkuppe 566 m, südlich Heidelberg	49°23'/8°44'
2	Hornisgrinde, 1164 m, östlich Achern	48°36'/8°12'
3	Hornberg, 900 m östlicher Anstieg, nördlich Säckingen	47°40'/7°57'
4	Leibenstadt, 347 m Adelsheimer Höhe, östlich Mosbach	49°22'/9°27'
5	Vaihingen, 300 m Höhe, norkwestlich Stuttgart	48°55'/8°56'
6	Heufeld, 850 m, südöstlich Mössingen	48°21'/9°7'
7	Egg, 440 m, bei Konstanz	47°42'/9°12'
8	Schweinsdorf, 450 m, östlich Rothenburg ob der Tauber	49°22'/10°15'
9	Hohenberg, 600 m, östlich Aalen	48°49'/10°11'
10	Rauenstein 1000 m, westlich Kempten	47°43'/10°13'
11	Schauinsland*, Schwarzwaldkamm östlich Freiburg	

* only particle collection

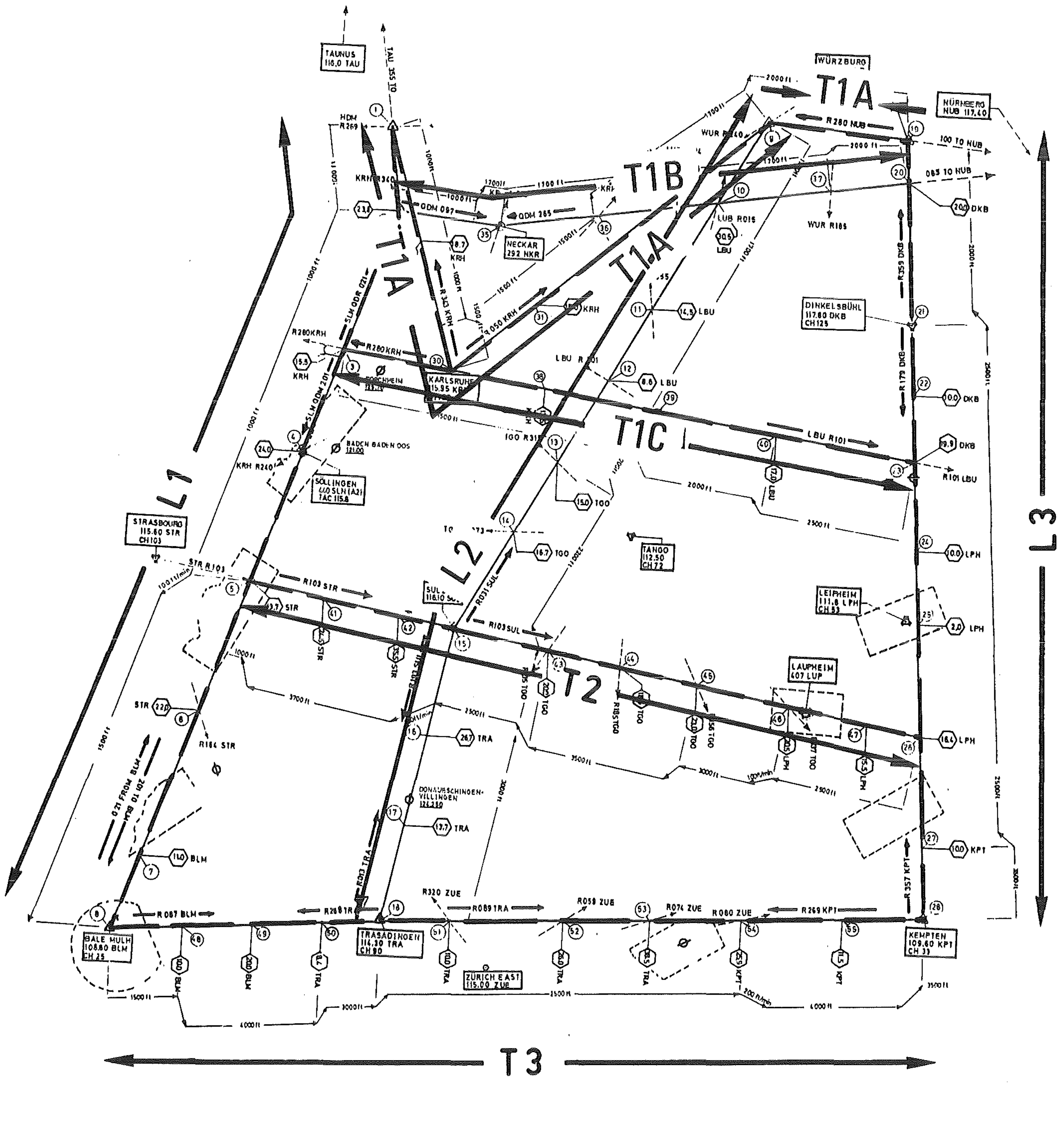
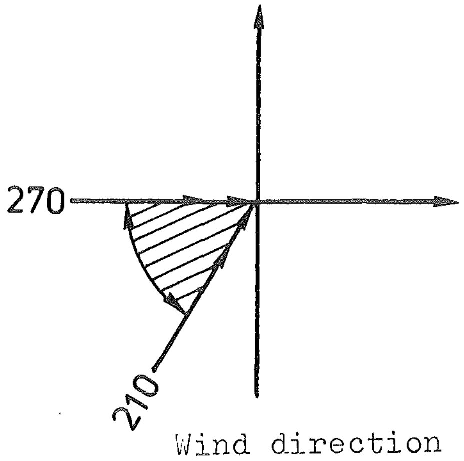


Figure 9/1: Description of the flight routes



Wind direction

Red Formation

Blue Formation

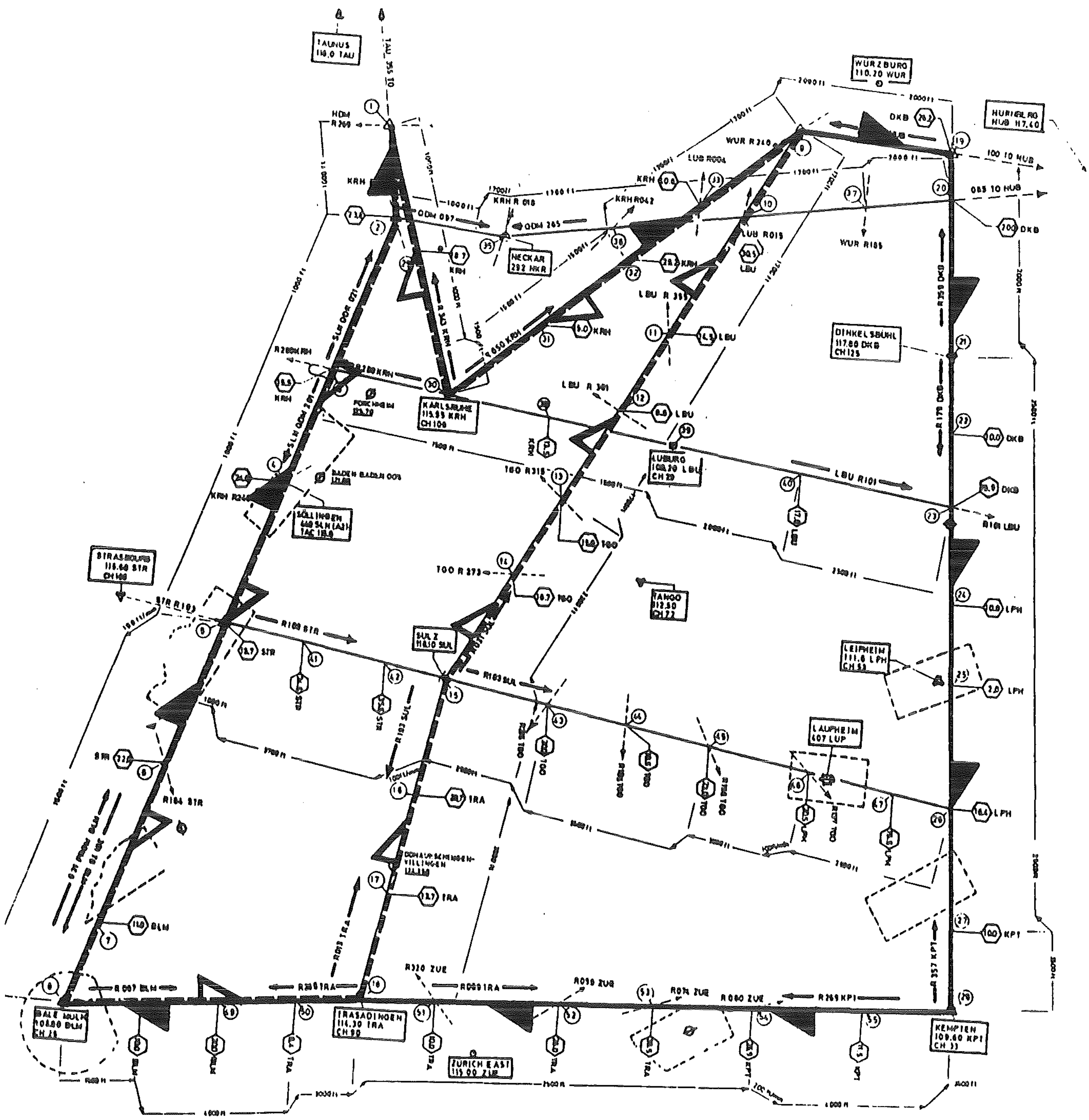


Figure 9/2: Flight pattern A

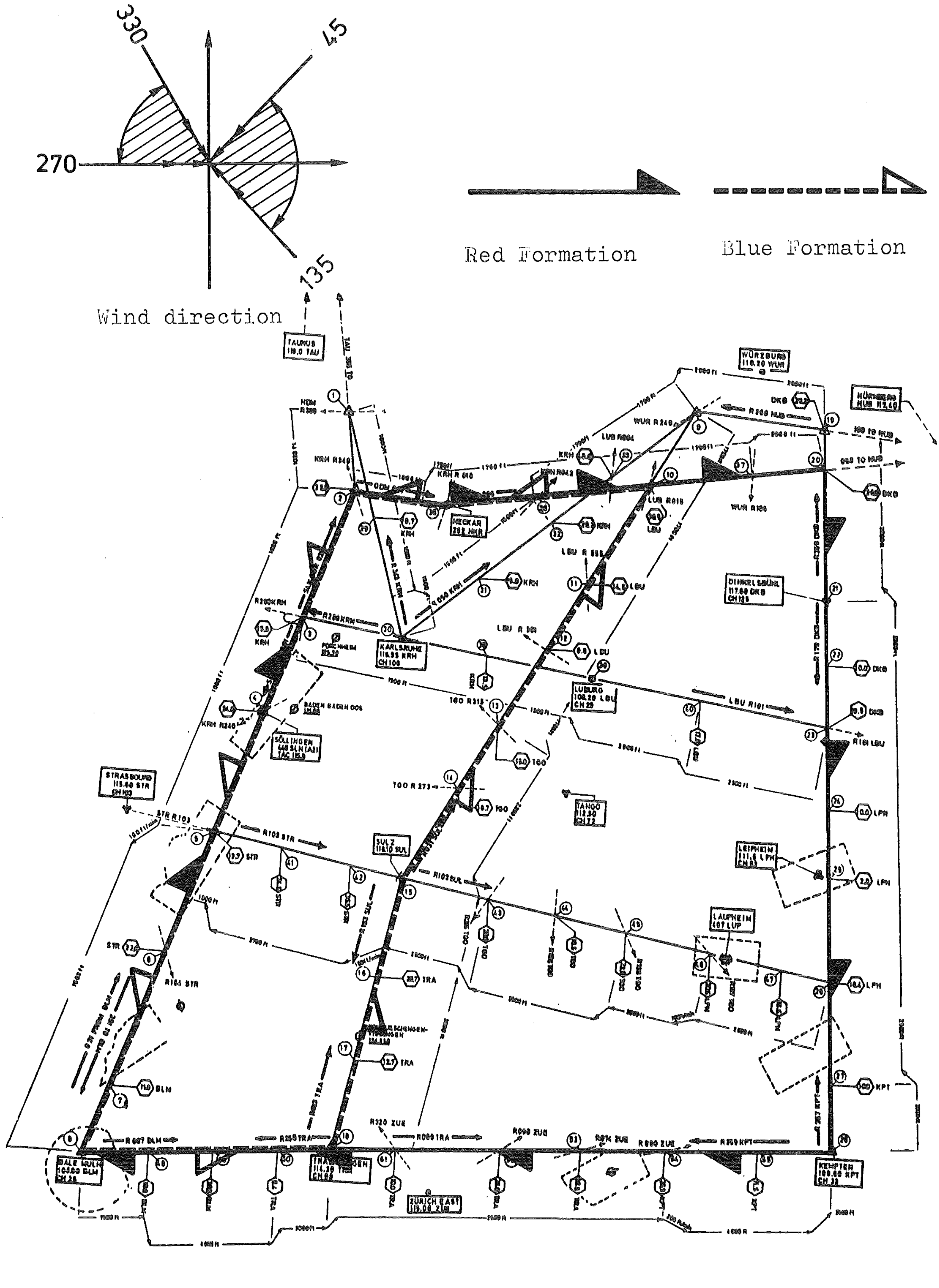
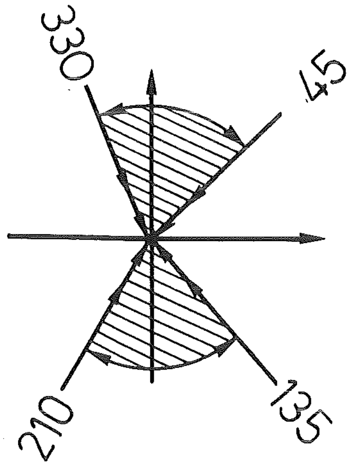
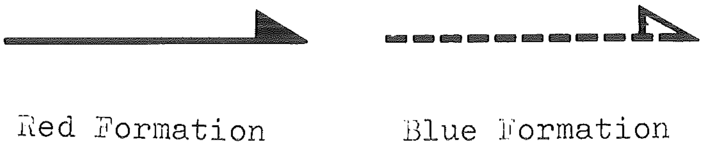


Figure 9/3: Flight pattern B



Wind direction



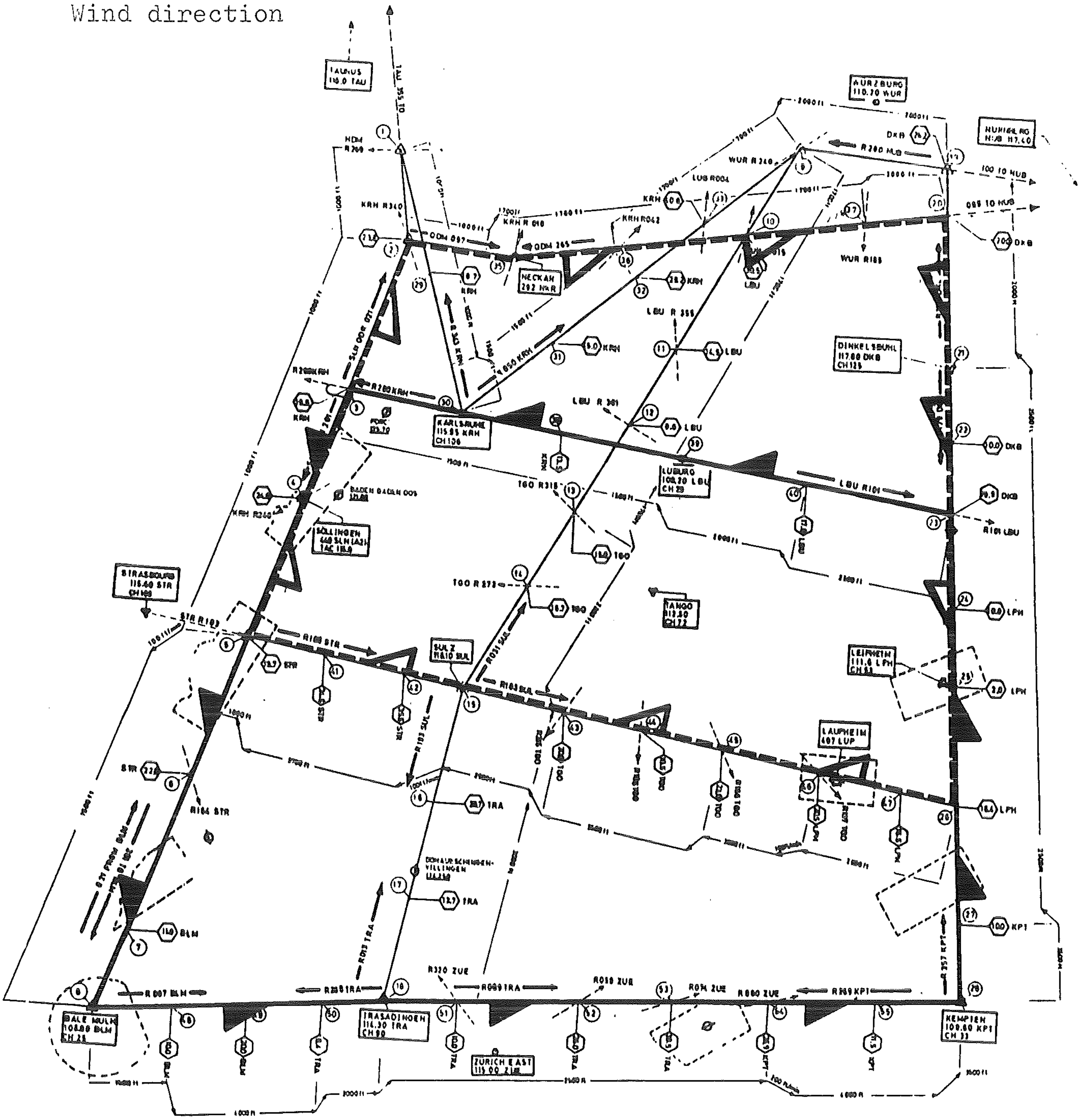


Figure 9/4: Flight pattern C

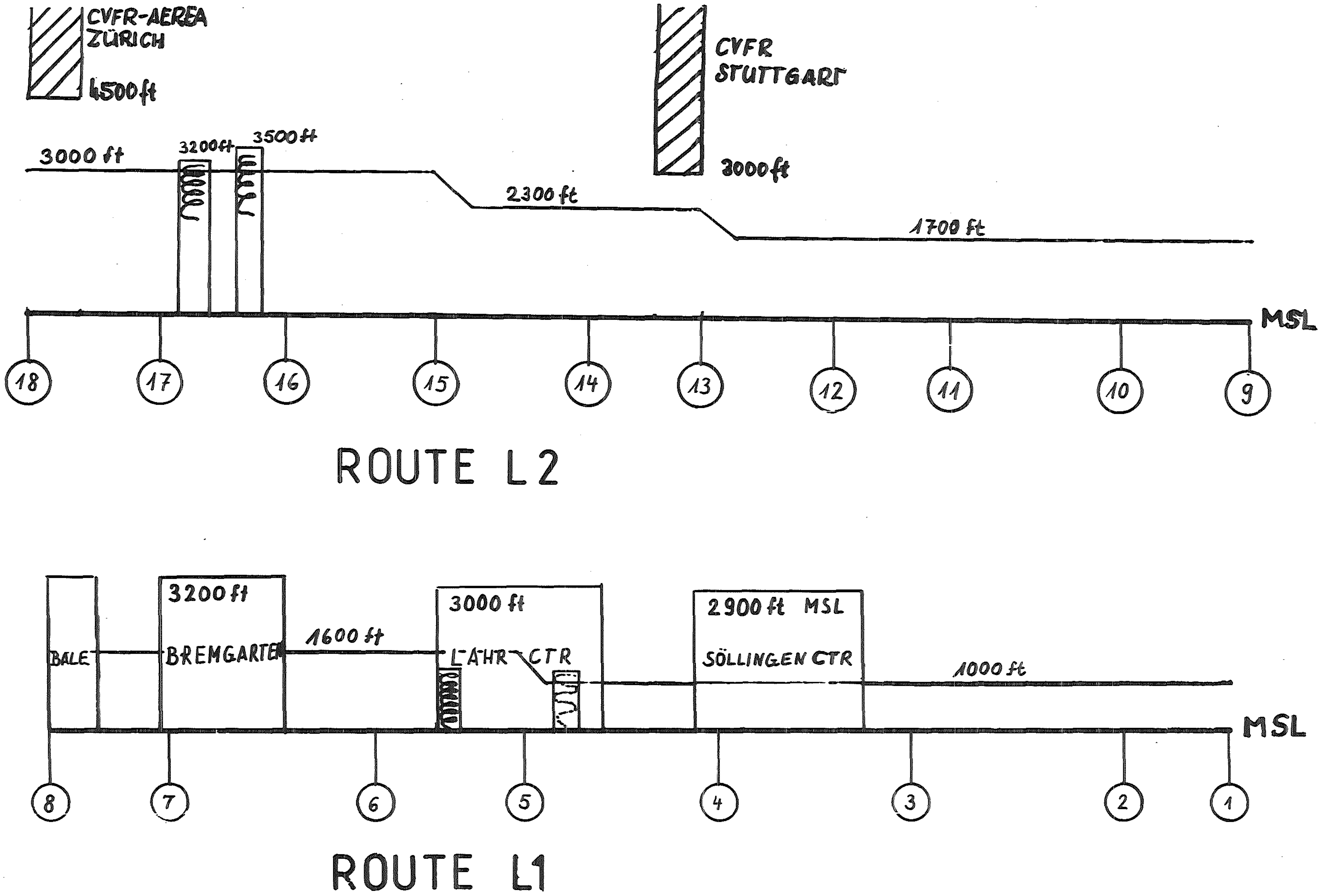


Figure 9/5: Rising and sinking of the lower flight niveau for flight routes L1 and L2
(Altitude refers to mean sea level)

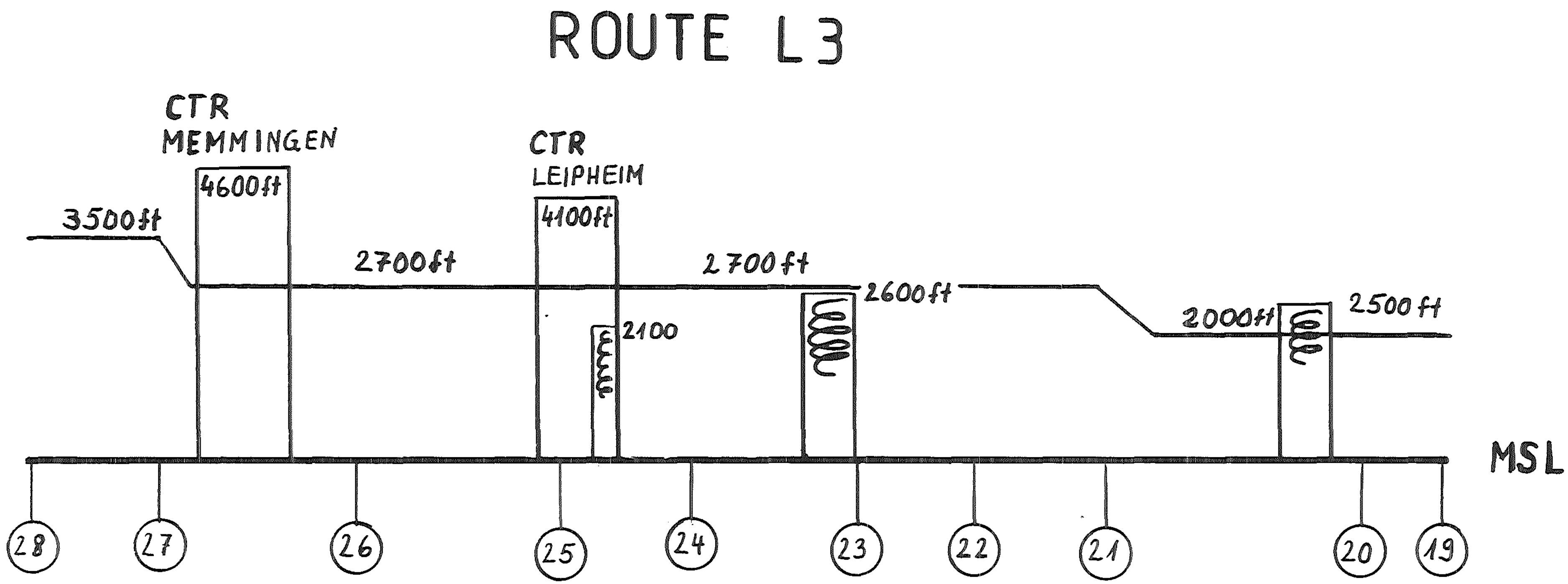
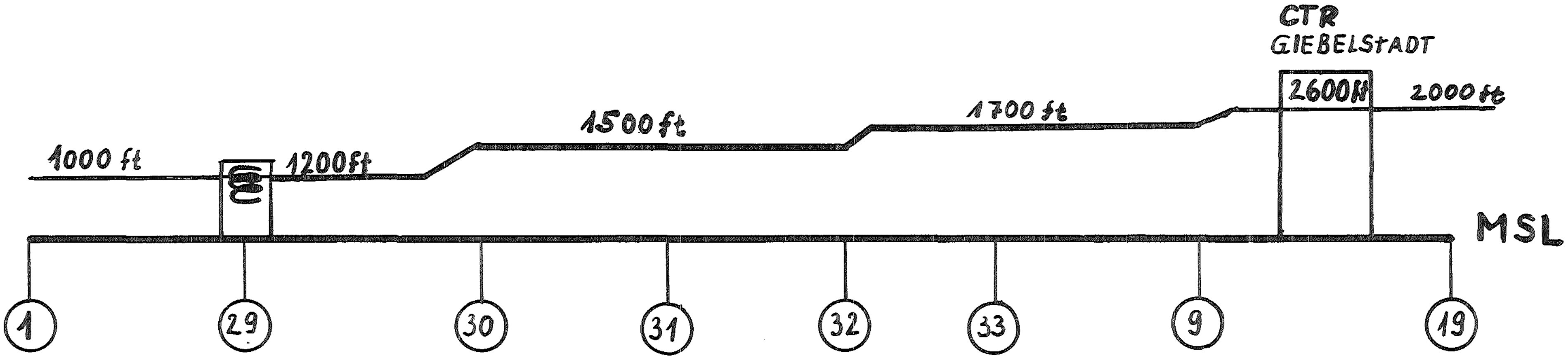
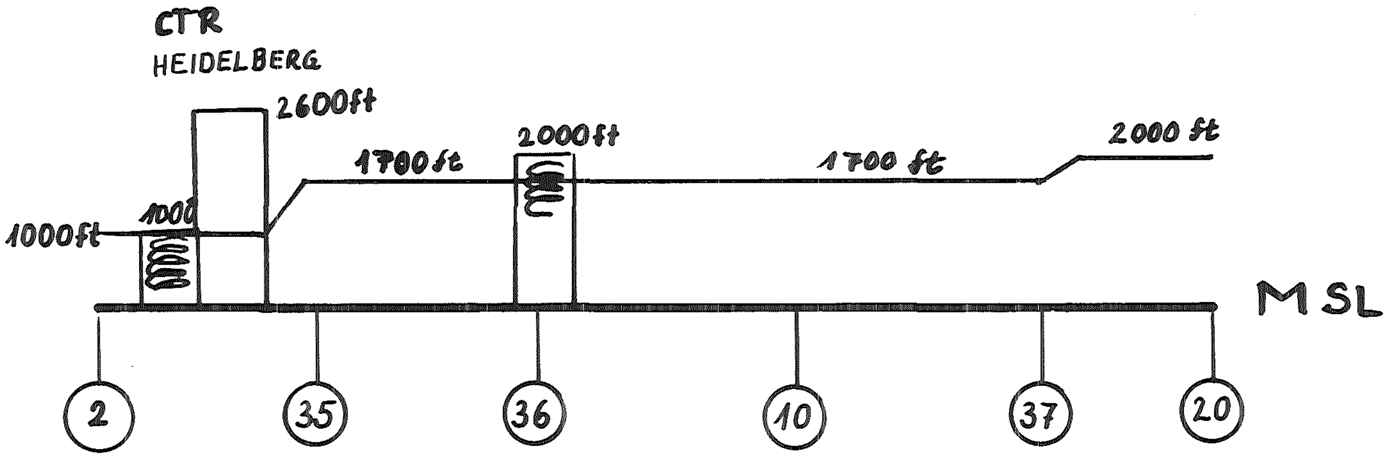


Figure 9/6: Rising and sinking of the lower flight niveau for flight route L3



ROUTE T1A



ROUTE T1B

Figure 9/7: Rising and sinking of the lower flight niveau for the flight routes T1A and T1B.

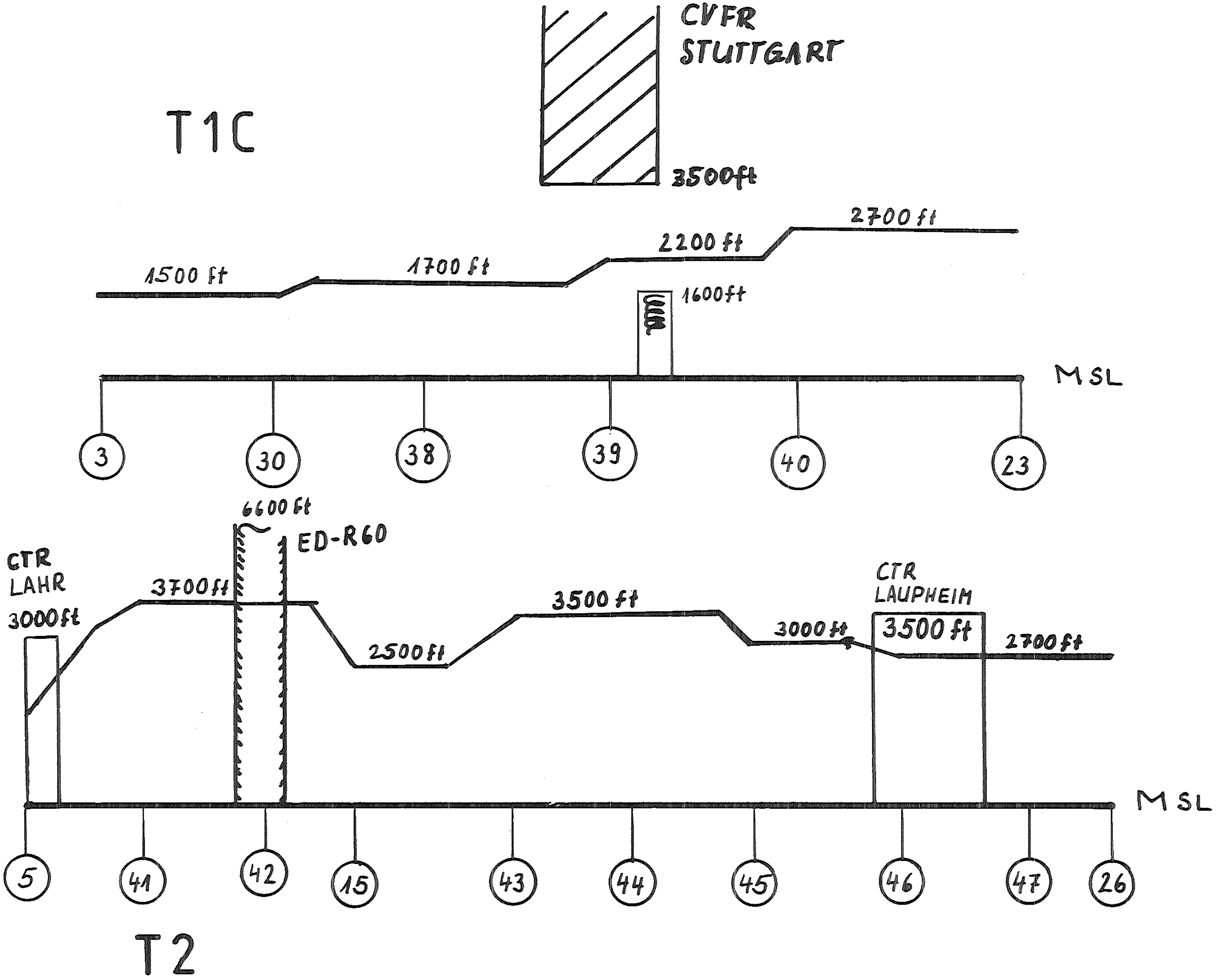
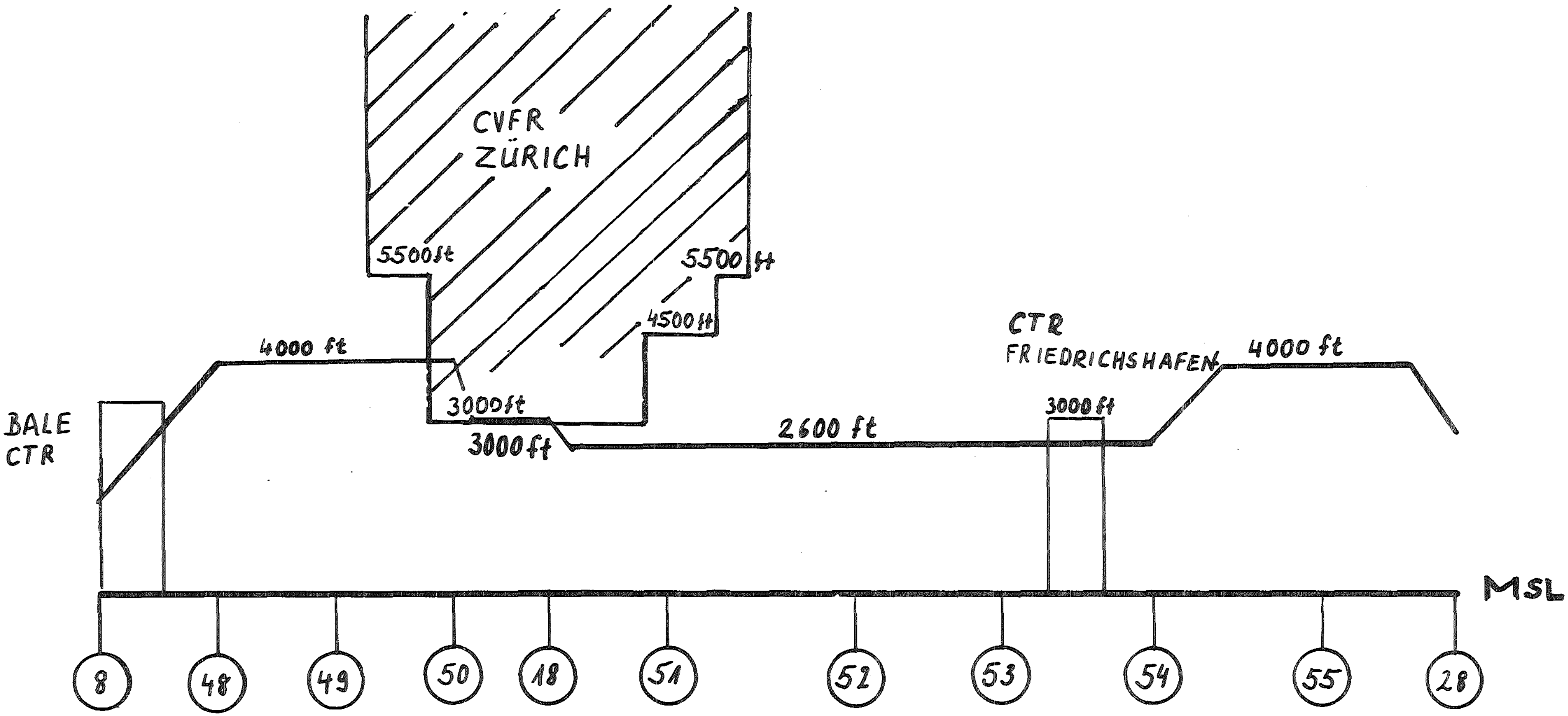


Figure 9/8: Rising and sinking of the lower flight niveau for the flight routes T1C and T2.



ROUTE T3

Figure 9/9: Rising and sinking of the lower flight niveau for the flight route T3

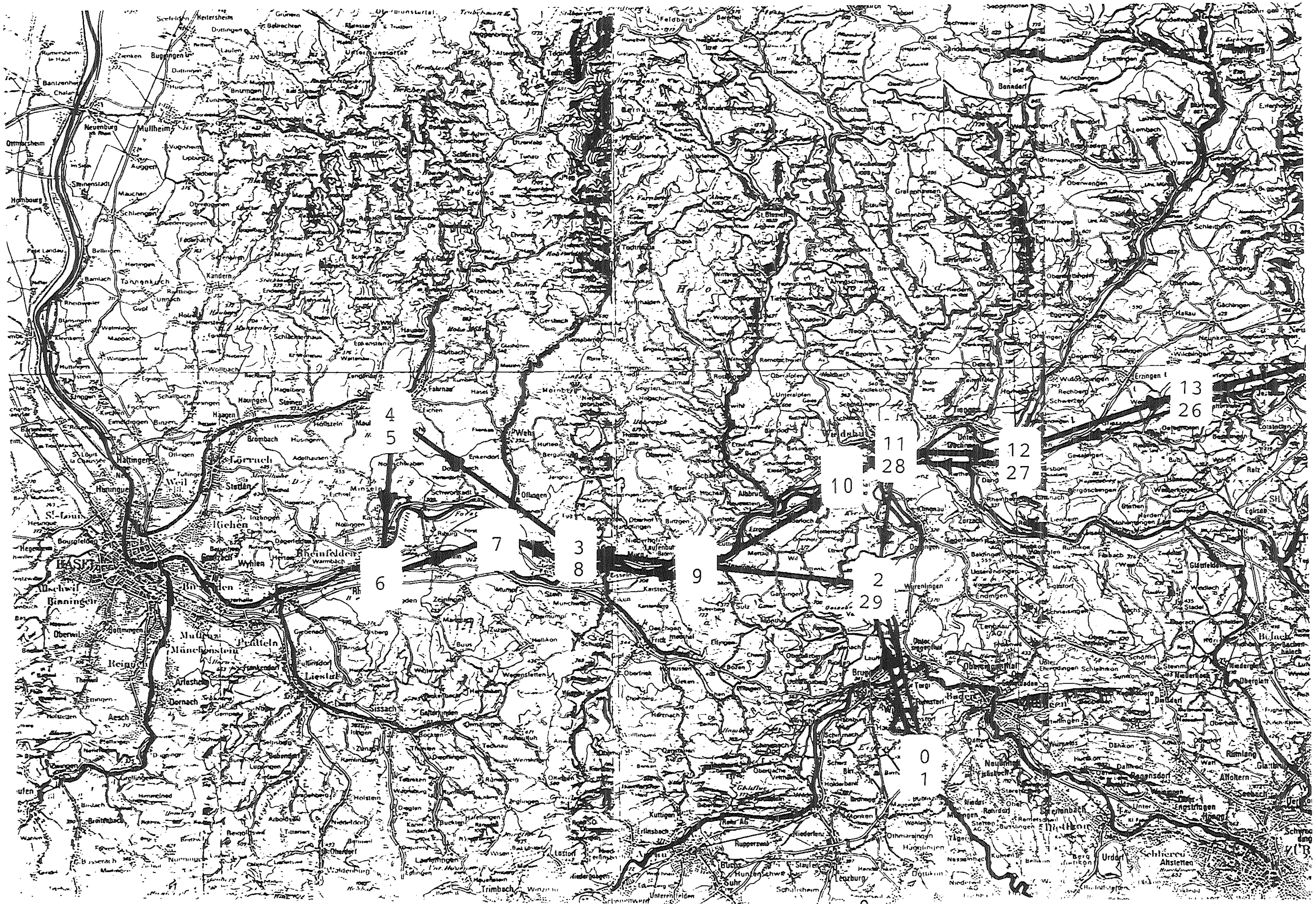
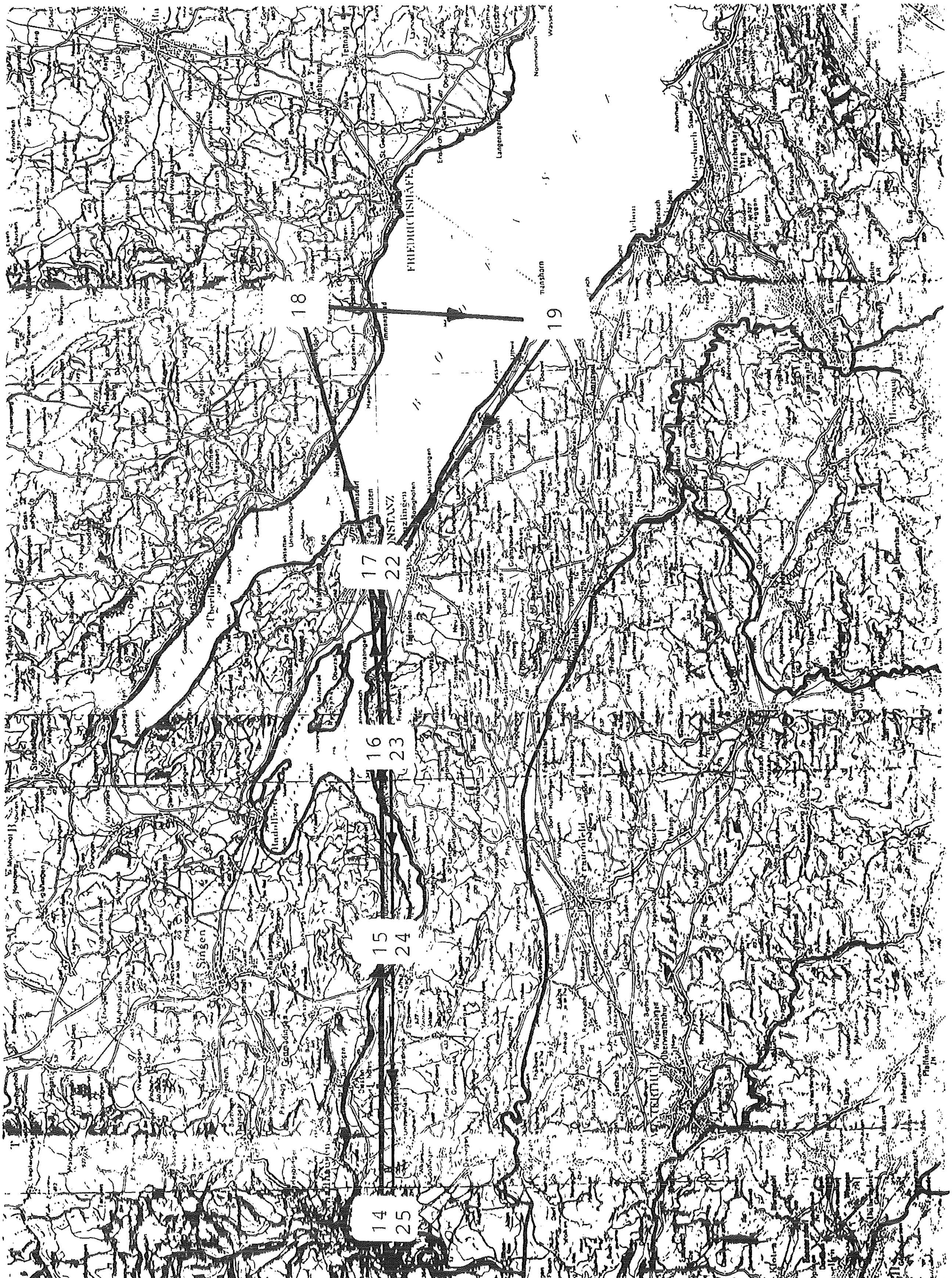


Figure 9/10: Flight route of the motor glider ASK-16 $\binom{0}{1}$ = airfield Birrfeld)



Continuation Fig. 9/10

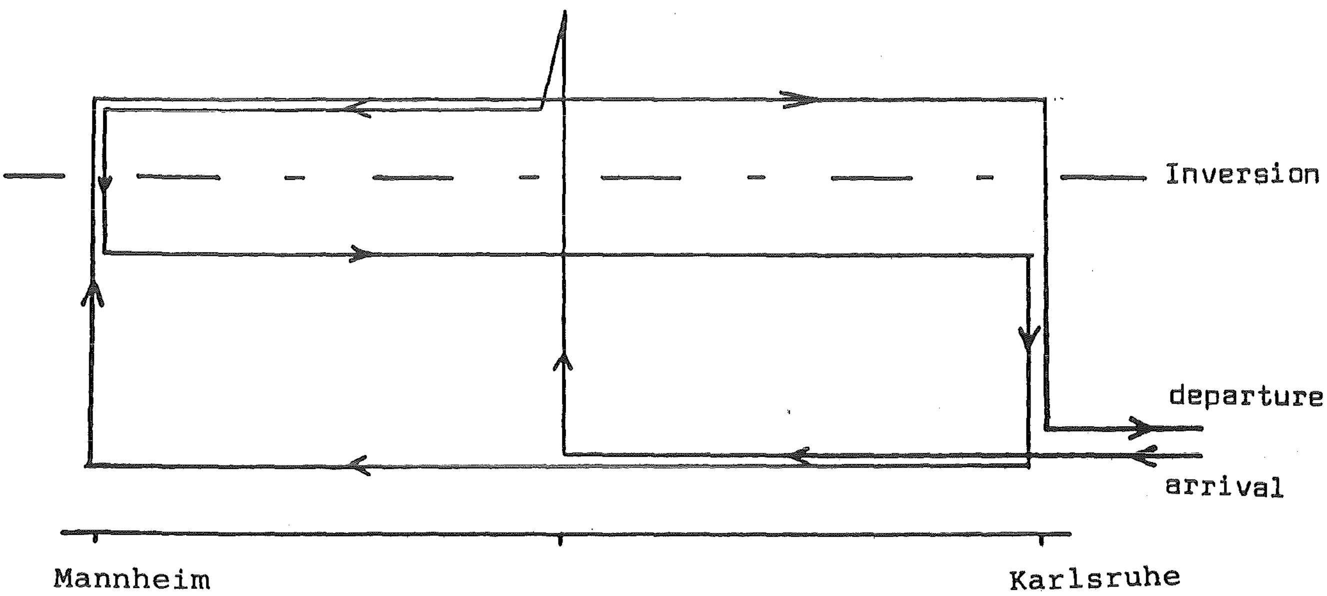


Figure 9/11: Vertical-profile of the Akaflieg Bölkow 207

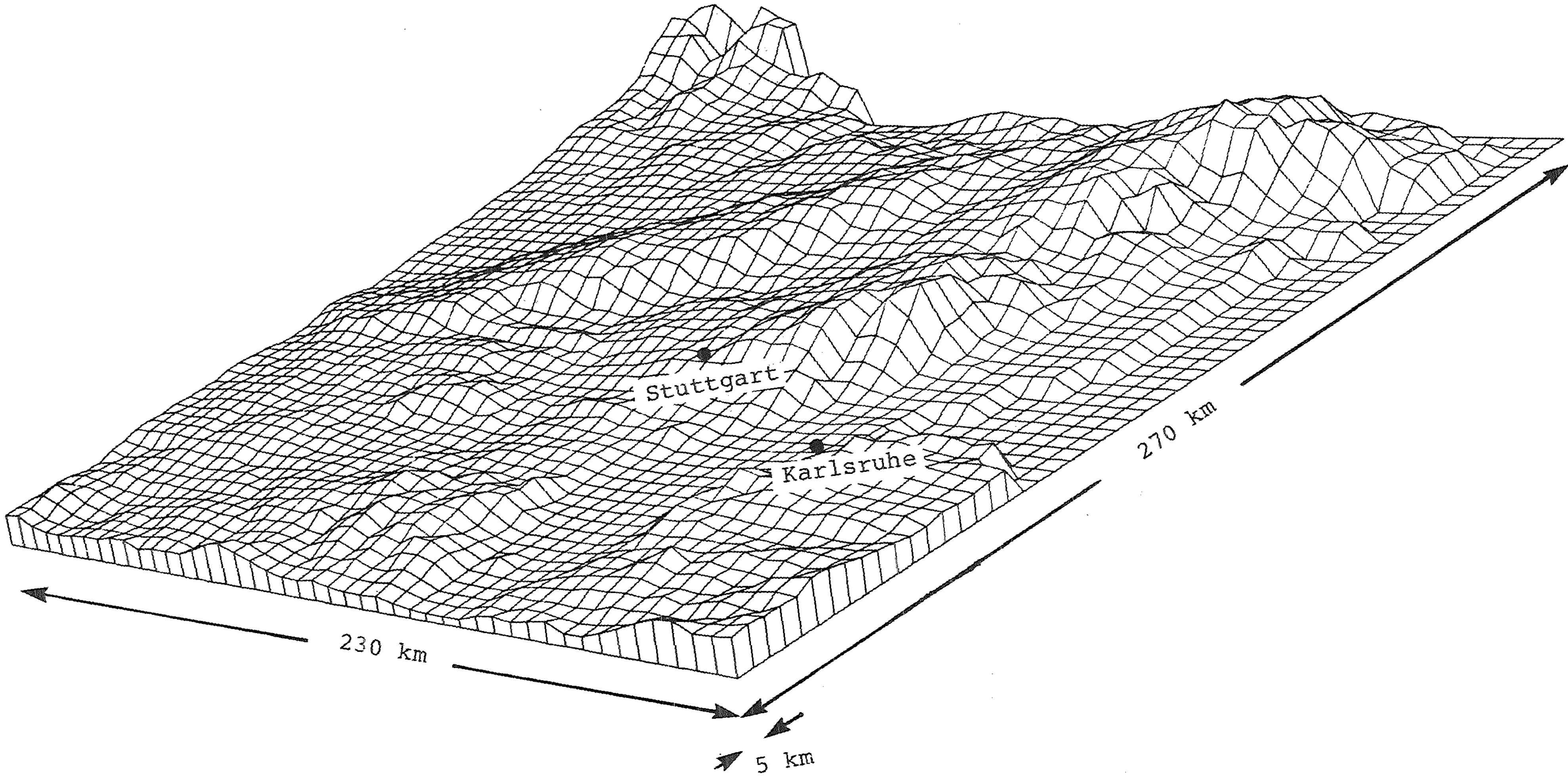


Figure 10/1: 3D-Plot of the model-area