Meteorological Navigation of Alpine Long-Distance Soaring Flights

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Abstract

The experience gained during the past years by the meteorological evaluation of data of alpine goal and return flights have shown that a further improvement of the forecasts and flight performances can be attained by applying statistical and empirical relations.

New statistical results as well as some relevant examples are used to demonstrate which synoptic patterns are especially suitable for long-distance flights in this region. Criteria are offered for an appropriate selection of the take-off base and the relevant forecast of the entire thermal development. Procedures are included for forecasting the meteorological parameters which are primarily affecting the flight planning and performance, as e.g. the onset, strength and duration of thermals as well as the height of the cloud base as function of time.

1. Determination of time during which thermals are usable

The time period during which thermals are usable plays a dominant role for the determination of the maximum distance of cross-country flights. In choosing the starting point pilots will therefore use airfields which are known for an early beginning of convection.

Figure 1 shows a statistical evaluation of the mean take-off times and their standard deviation of 97 long-distance cross-country flights in the northern part of the Alps, i.e. triangle and goal and return flights of more than 600 km. A significant increase of the earliest time of departure was found in a direction from east to west. While the departure times from Turnau are around 08.30 CET, they are delayed by thirty to sixty minutes per 100 km in westerly direction. A comparison with earlier data (1) shows no im-

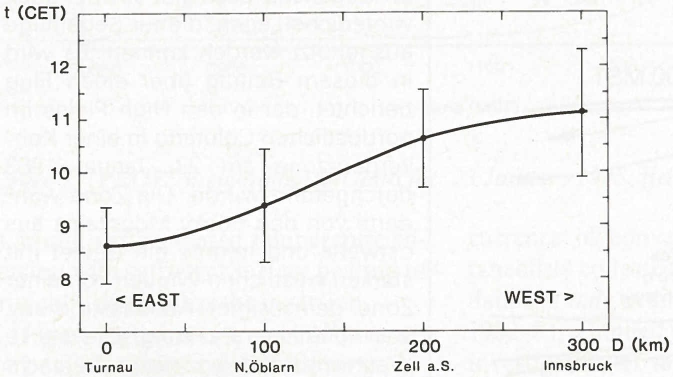

FIG. 1 REGIONAL DEPENDENCY OF EARLIEST TIME OF DEPARTURE FOR ALPINE LONG DISTANCE CROSS COUNTRY FLIGHTS

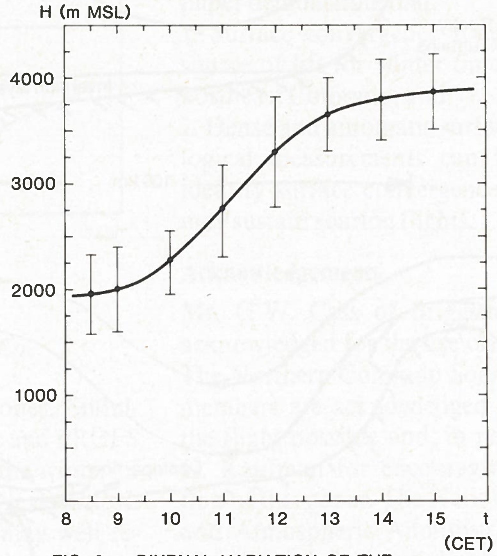

FIG. 2 DIURNAL VARIATION OF THE HEIGHT OF CLOUD BASE

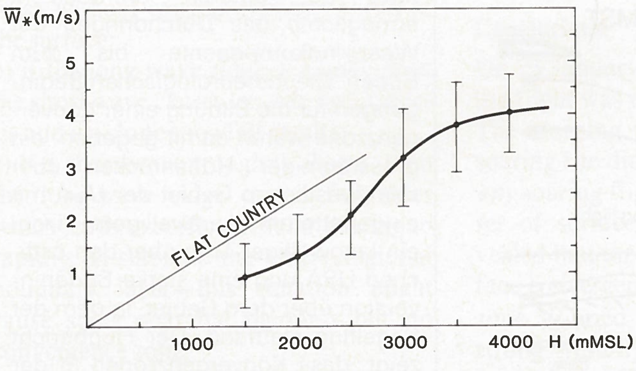

FIG. 3 MEAN LIFT RATES AS FUNCTION OF THE HEIGHT OF CLOUD BASE

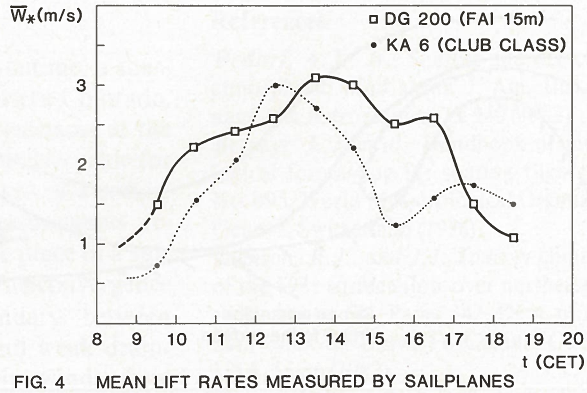

FIG. 4 MEAN LIFT RATES MEASURED BY SAILPLANES OF DIFFERENT CLASSES DURING MAY 31 1981 AND JUNE 2 1982

portant difference, but the presented results are based on a greater number of flights, and are thus of greater statistical significance.

The departure times from other airfields like Mariazell, Timmersdorf, Trieben or St. Johann fit well into this scheme. Departures from Niederöblarn or Zell a. See have a greater advantage only in the event as air mass change over the Eastern Alps has led to stratus or stratocumulus cloud cover. Under certain conditions, the high-pressure cell being located northeast or east of Vienna, departure points east of Turnau make even earlier times possible. Airfields like Innsbruck or Reutte which are located further to the west are not so well situated for very long goal and return flights, although they have advantages as far as big triangle flights over the Alps are concerned.

The question is difficult to answer at which time the usable convection ceases over the Eastern Alps. Methods used over flat country, as for example forecasting the equivalent potential temperature, fail in most cases. A suitable criterion for this forecast is the prevailing wind direction in the 850-hPa level during early afternoon. In case the mean flow moves from south or southwest and shows a stable stratification, the final glide altitude should be reached between 16.30 and 17.00 CET. Without such an advection long-distance flights have a good chance to be successfully completed, as the last direct thermals will be replaced by evening lift at around 18.30 CET, even without cold air advection; this often makes final glides possible until sunset.

2. Meteorological parameters for flight planning

Long goal and return flights require turning points within Engadine, Vorarlberg or Graubünden. For the flight planning the question is essential whether the cloud base reaches heights near midday which make far approaches of the turning points possible. This is especially important for flights west of a line between Flüelapass and Arlberg, to make sure that a safe return to the Inn Valley is possible.

Figure 2 shows the typical increase of the height of usable thermals. Totally 26 long-distance flights by Breuer, Haggenmüller, Schubert and Leykauf were processed covering distances between 720 and 960 km. Contrary to earlier results (1) which showed a mean cloud base of nearly 2600 m MSL after departure time, the present results show significant lower minimum cloud bases for a good start. In the vicinity of Innsbruck or Imst the cloud base should be at least around 2700 m MSL by midday to have a good chance for a successful flight from the statistical point of view.

The mean rate of climb is the next im-

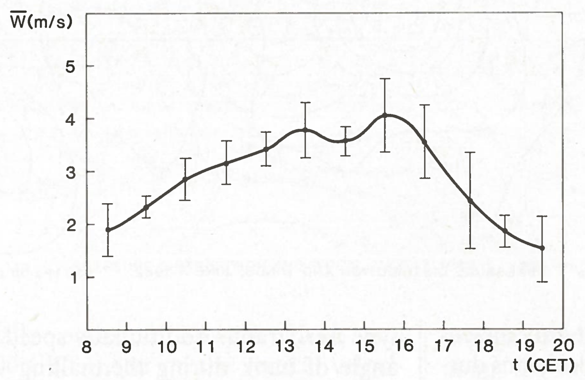

FIG. 5 DIURNAL VARIATION OF MEAN VERTICAL AIR VELOCITIES AND STANDARD DEVIATION

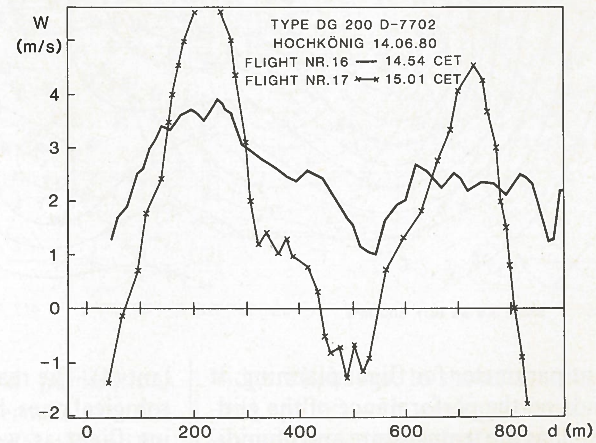

FIG. 7 TYPICAL EXAMPLE FOR CROSS SECTIONS OF THERMALS IN THE ALPS
(×—× 150 FT ABOVE RIGDE, — 1500 FT ABOVE RIGDE)

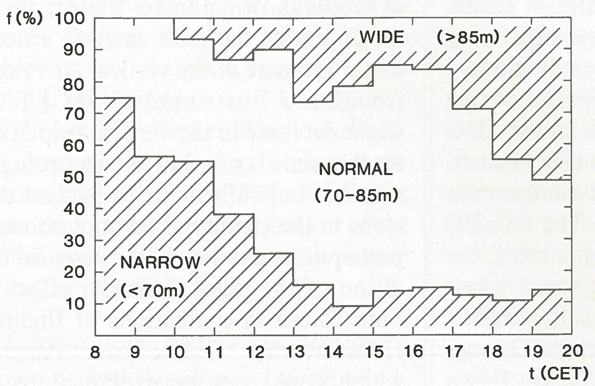

FIG. 6 FREQUENCY OF TYPES OF THERMALS DEFINED BY THE RADIUS OF TURN

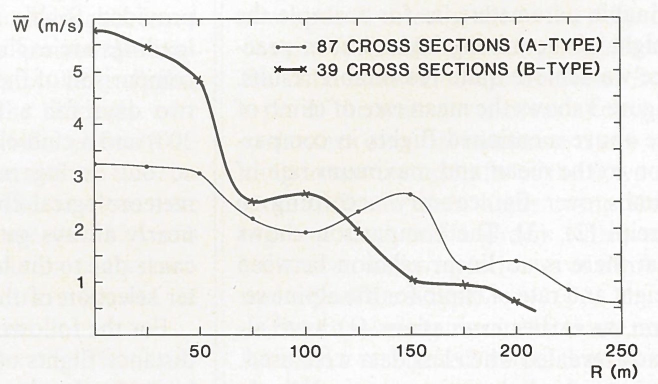

FIG. 8 MEAN HORIZONTAL CROSS SECTIONS OF ALPINE THERMALS

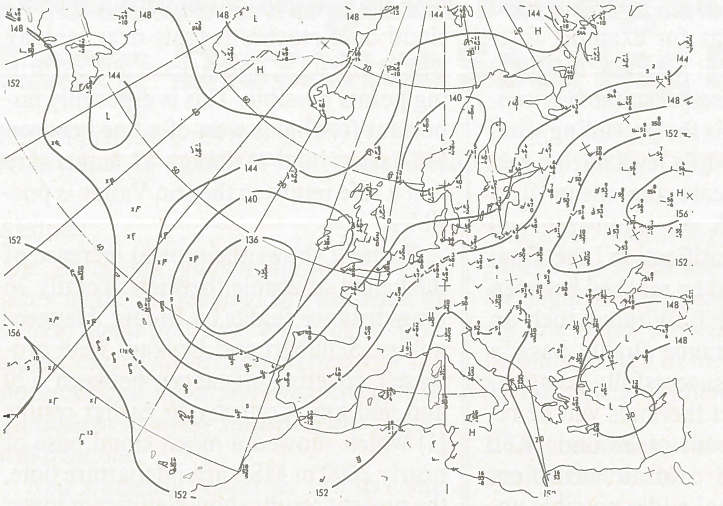

FIG. 9a PRESSURE DISTRIBUTION AND WINDS, MAY 31 1983 850 hPa 00GMT

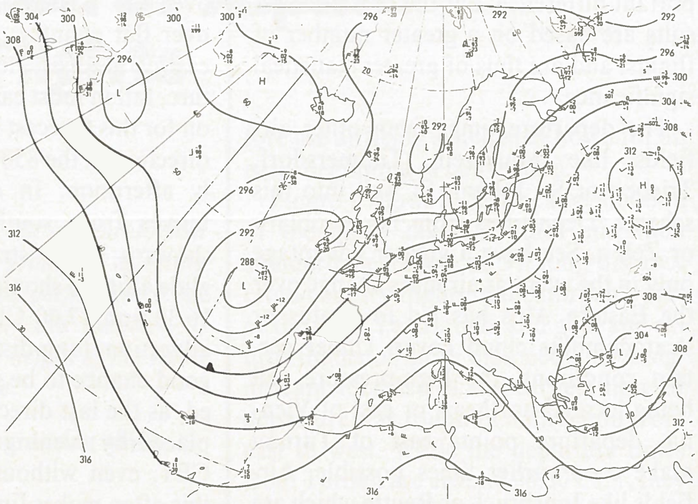

FIG. 9b SAME AS 9a BUT 700 hPa

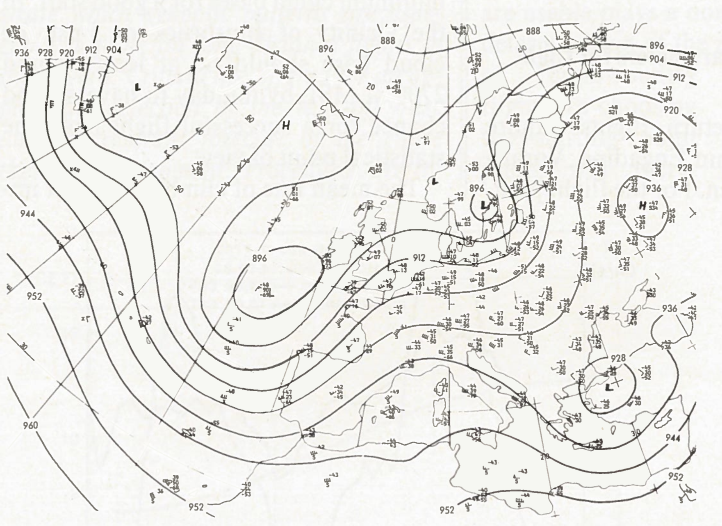

FIG. 9c SAME AS 9a BUT 300 hPa

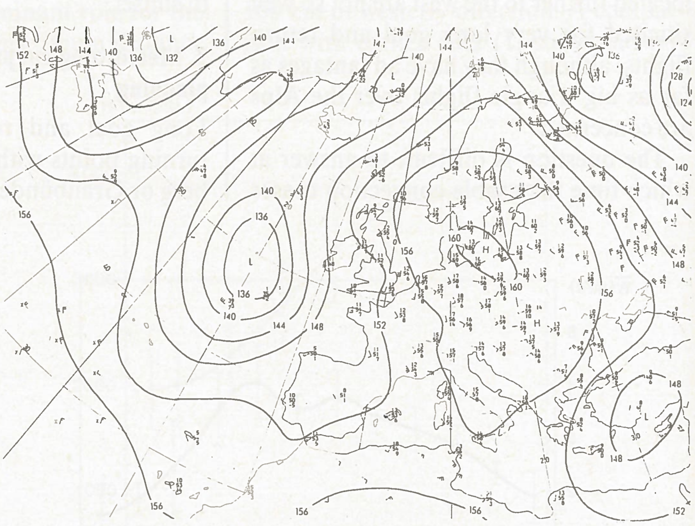

FIG. 10a PRESSURE DISTRIBUTION AND WINDS, JUNE 4 1982 850 hPa 00 GMT

portant parameter for flight planning. It depends on the performance of the glider as well as the temperature and humidity gradient, height of mixing layer, wind, etc. Theoretically it seems to be nearly impossible to obtain an estimate for the average thermal strength from easily obtainable parameters, as for example the height of the mixing layer, but in practice we achieve quite reasonable results. Figure 3 shows the mean rate of climb of the above-mentioned flights in comparison to the mean and maximum rate of climbs over flat country according to Kreipl (2), (3). The comparison shows that there is no linear relation between height and rate of climb for the alpine region, as earlier evaluations (1) have already revealed when less data were used. The standard deviations are relatively large, but similar to the results of Vaillant (4). The reasons are not only meteorological ones, but tactical decisions during flight as well as different performances of gliders.

Flying under the same weather conditions gliders of different performance should achieve different rates of climb, provided flights using very high wing loadings are excluded. Figure 4 shows a comparison of the mean lift rates during two days for a 15-m-class glider (DG 200) and a club-class glider (Ka 6) carried out during relatively homogeneous meteorological conditions. The DG 200 nearly always gets higher lift rates, because due to the higher glide ratio a better selection of the thermals is possible.

For the following evaluation 12 long-distance flights of 600 to 780 km flown by the author have been analysed using traces of a calibrated barograph of the type Aerograph. Additionally speed and angle of bank during thermalling were measured to eliminate the sink rate of the glider. Thus it is possible to get some information about the type of the thermals. The average thermal strenght as function of time is shown in figure 5. From the onset of usable thermals there is a nearly linear increase of the vertical air velocity from 2 to 3.7 m/s until 13.30 CET. The slight decrease in the vertical velocity after that time is not due to meteorological reasons, but rather due to tactical decisions in the vicinity of turning points, or perhaps due to a low in the physical condition of the pilot. A similar effect has been found in evaluations of flights of Hans Werner Grosse over Australia which could not be explained by the meteorological situation. The maximum values of mean vertical air velocities

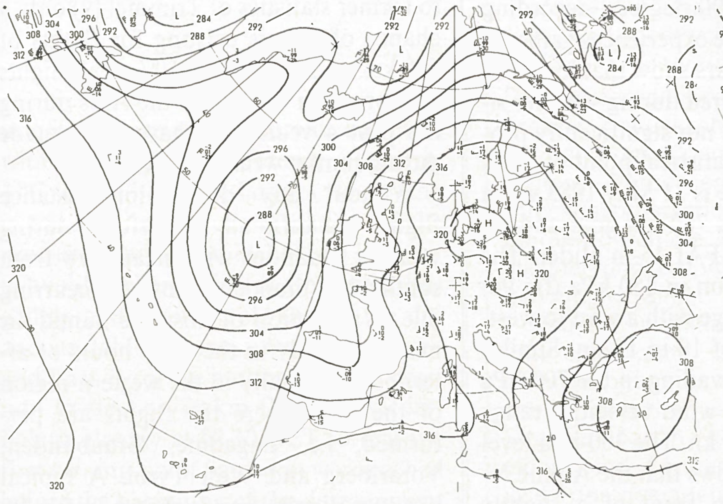

FIG. 10b SAME AS 10a BUT 700 hPa

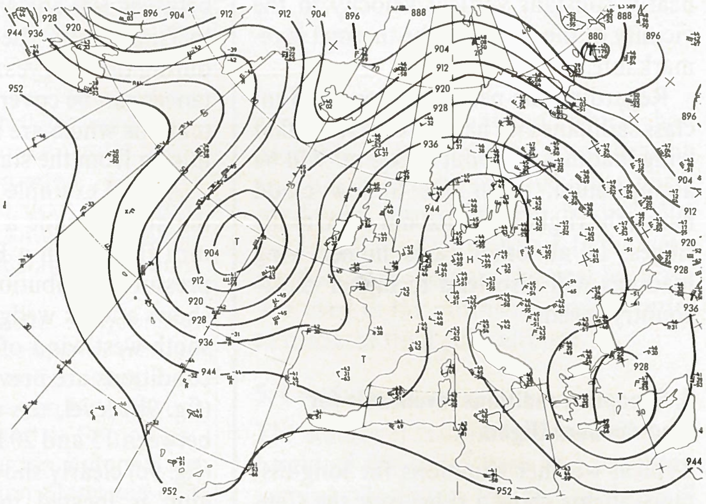

FIG. 10c SAME AS 10a BUT 300 hPa

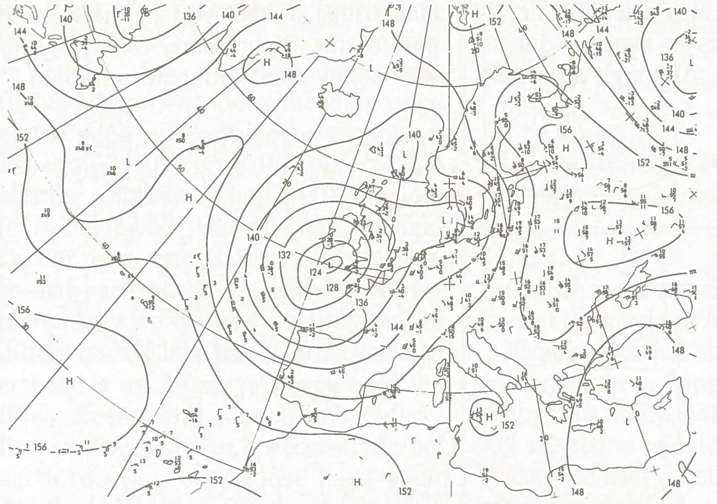

FIG. 11a PRESSURE DISTRIBUTION AND WINDS, MAY 17 1983 850 hPa 00 GMT

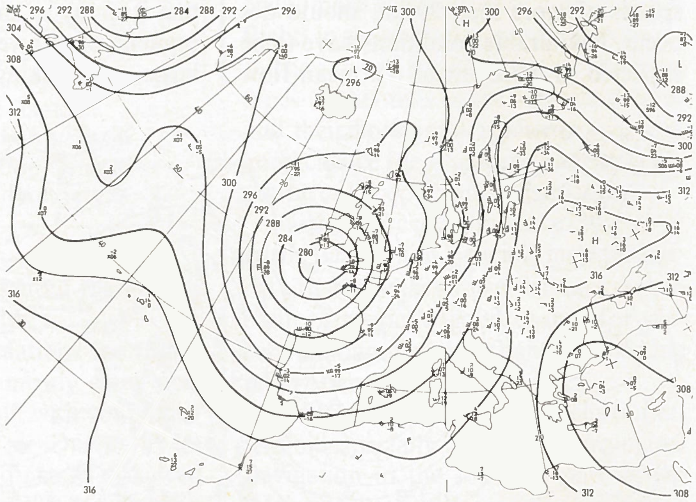

FIG. 11b SAME AS 11a BUT 700 hPa

usually occurred between 15.00 and 16.00 CET. Later on the vertical velocities decreased continuously to 1.5 m/s.

If we try to distinguish between three types of thermals by using the information about the thermalling technique, the results are derived which are shown in figure 6. During the first stage of the flights narrow thermals required steep circling, this happens with a frequency of 75%. Later on the contribution of narrow thermals decreased and reached approximately 10% at 13.00 CET. As shown in figure 6 the contribution of the normal and wider thermals increased during the rest of the flight.

3. Structure of the thermals in the Alps

Structure and frequency of thermals have a strong influence on the optimum wing loading, see e.g. Pirker (6). Although there are several publications about the structure of thermals over flat countries, see Konovalov (6), (7) and Estival (8), there are no data available for alpine regions.

The following gives an evaluation of flights with a 15-m-class glider of the type DG 200 carried out during the last 4 years to investigate the horizontal structure of thermal updrafts. Only flights were selected, where the thermals were marked at least by one other glider in order to traverse the thermal as close as possible to the center. The traverses were made with an average speed of 85 km/h to achieve a good resolution of the horizontal structure. 126 traverses out of nearly 200 could be used.

Figure 7 is a typical example for 2 successive traverses over the Hochkönig. Both traverses cross the same part of the ridge. Flight No. 16 shows a strong thermal updraft with weak gradients, corresponding to Konovalov's A type of thermals (7). Flight No. 17 shows the B type with strong updraft but large horizontal gradients. The comparison of the measurements shows that the strong and narrow updraft directly above the ridge becomes wider with increasing height while the maximum velocities decrease. Both types of thermals never occur as close to each other over flat countries. Steep circling in narrow updrafts of the B type is more difficult when higher wing loadings are used, while gliders with water ballast can achieve good rates of climb in updrafts of the A type.

The concluding results of these measurements in Figure 8 show, that also in the Alps in most cases, namely in 70%, relatively flat thermals were found; the nearly constant vertical velocity in the vicinity of the centre of the thermal is remarkable.

Regarding the performances of 15-m-class sailplanes we have to conclude, that wing loadings of about 35 kg/m² will be an optimum, when due to low cloud bases, the flight is carried out close to the ridges. In all other cases higher wing loadings will also lead to higher cross-country speeds.

4. Synoptic conditions favourable for long-distance flights

Typical weather situations for long-distance flights show a ridge over the Central Alps. Up to the 700-hPa level wind speeds of more than 20 kn. should not occur. Favourable conditions have to be expected in direction of the mean flow between 300 and 90 degrees, according to Trimmel (9). The experiences gathered during the past years show that long distances can be covered during weather situations which are not significantly promising from the statistical point of view.

A good example is 31 May 1983 when the author made a 780-km goal and return flight with a FAI 15-m glider. The pressure distribution in 850 hPa (fig 9a) shows a weak wedge with a west to west-south-west wind of 10 to 15 kn. Similar conditions are prevailing in the 700-hPa (fig. 9b) level, the wind velocities range between 15 and 20 kn. The 300-hPa level (fig. 9c) clearly shows that the Alpine region is located in front of a slightly marked upper ridge of high pressure, that is to say in an area where the development of showers is avoided due to large-scale sinking. Although according to former statistics of Trimmel (9) only a chance of 10% is existing for flights of 500 km or more, nearly 50% of all flights of more than 600 km in the Alps during the past 4 years may have been made during similar weather conditions.

Without any doubt long-distance flights are difficult to perform during weather situations with mean flow from south when thunderstorms are occurring due to advection of unstable humid air masses already in the early hours of afternoon especially in the western region of the area where the flights are performed, i.e. Engadine, Graubünden, Vorarlberg and West Tyrol. A typical pressure distribution is shown in fig. 10. A weak southern current is crossing the main ridge of the Alps in the western part of the flight route, relatively dry with a dew-point difference of about 7°

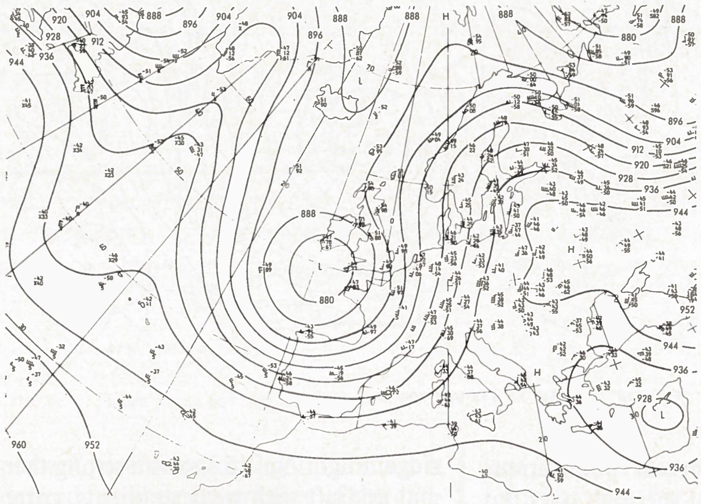

FIG. 11c SAME AS 11a BUT 300 hPa

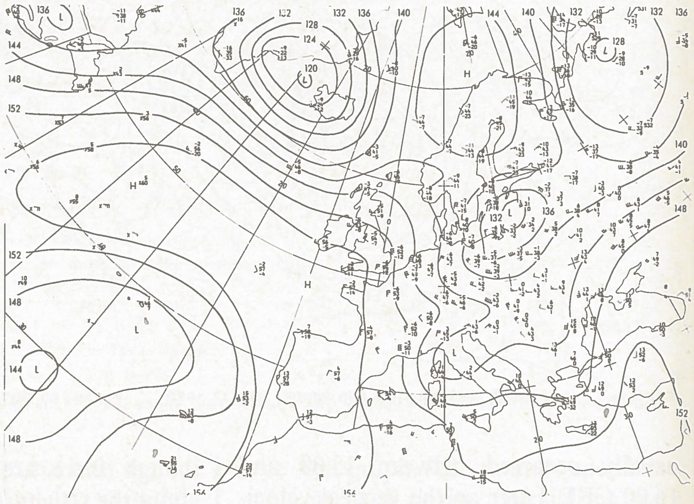

FIG. 12a PRESSURE DISTRIBUTION AND WINDS, APRIL 13 1983 850 hPa 00 GMT

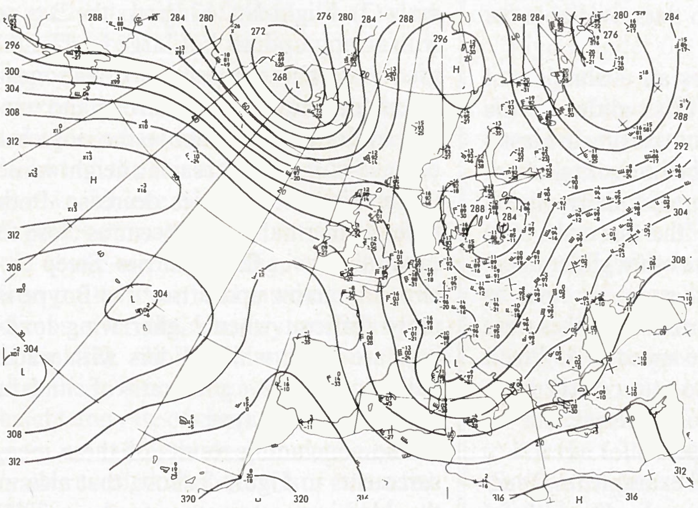

FIG. 12b SAME AS 12a BUT 700 hPa

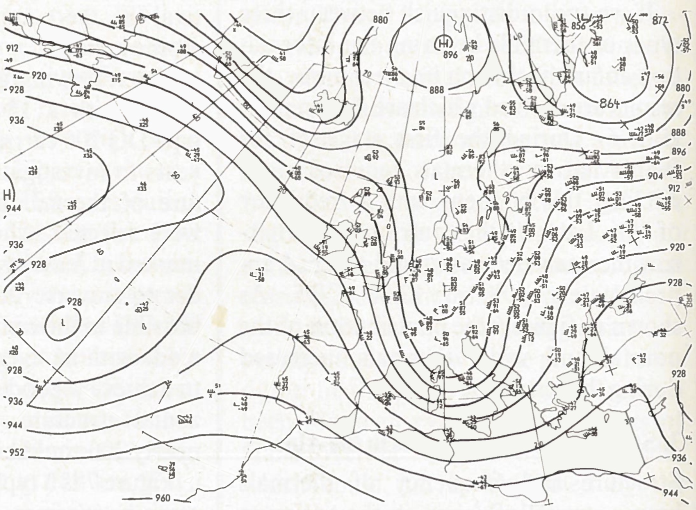

FIG. 12c SAME AS 12a BUT 300 hPa

in 850 hPa, relatively humid, however, with a dew-point difference of partly 3 °C in 700 hPa. The large-scale sinking is too low in the configuration of the pressure distribution in 300 hPa in order to avoid the formation of Cbs in the Engadine and West Tyrol. Due to the dry and unstable air mass over Steiermark and East Tyrol the author was in a position to start a 770-km flight at Niederöblarn already at 08.30 CET so that the first turning-point Samedan was reached before the beginning of the development of showers shortly after 13.00 CET and the flight was successfully finished in spite of all forecasts.

Without any doubt long-distance flights using waves along the main ridge of the Alps will become very popular. Especially suitable for this purpose are weather conditions where the flow velocity in the lowest 3000 m is not too high, i.e. not more than 20 kn. (fig. 11a, 11b), so that parts of the route may be flown thermically if the distances between the different wave lifts are too large. In larger heights an intensive increase of the flow velocity with simultaneous advection with very dry air is necessary in order to develop on the one hand good waves, and on the other hand to have a low cloud cover as small föhn gaps may be very risky for long-distance flights. During the weather situation which may be considered as model (fig. 11a–11c) flights were performed of 550 to 800 km in the area of the East Alps by using thermal lift and waves, the largest heights reached were 10,000 m MSL in the area between Grossglockner and Kitzsteinhorn.

All statements made up to now refer to the central and eastern part of the northern Alps although – as we know since the first spectacular 1000-km flight of Frederico Blatter across the Alps with Nimbus 3 on 13 April 1983 – the longest flights can be made in the south of the Alps. There are not yet many data available for a statistical evaluation of long flights in the south Alps. However, it is doubtful whether such simple connections can be found for the function of the cloud base and the rate of climb during the course of the day for larger areas, as here the regional orographic differences and thus also the meteorological ones, are much more pronounced than in the area of the northern Alps.

Typical weather situations for flights in the southern Alps mostly show northern flow components with simultaneous advection of cold air. Due to the lee effects the heavy cloudiness is dissolved along the main ridge of the Alps, whereas from the south a flow of unstable humid air masses towards the main ridge is suppressed. The weather situation of 13 April 1983 does not show all the abovementioned characteristics, and is therefore rather uncommon for flights in the southern Alps.

In the 800-hPa and 700-hPa level (fig. 12a, 12b), a windward ridge of high pressure is seen at the north side of the Alps and the formation of a depression at the south side. In higher levels, however, e.g. 300 hPa (fig. 12c), there is a marked trough over the Central Alps. For this reason a large-scale lift is superimposed over the lee effects on the south side of the Alps leading to a disappearance of the clouds in the lower levels. Consequently Blatter was confronted during his record flight with several snow showers, and on his return flight he had to circumnavigate the Basin of Bolzano in the south from the first turning-point as the quick return flight on the northern route across the Sarntaler mountains was impossible. Near the first turning-point flat waves were encountered which had probably to be attributed to a shearing and not to lee waves (700 hPa: north wind with approximately 20 kn., 300 hPa: south wind with 50 kn.). In the western part of the route a classical lee wave was used in the northwest flow in order to reach the final glide altitude.

Zusammenfassung

H. Leykauf, Meteorologische Navigation bei Langstreckenflügen im Segelflug im Alpenraum.

Die meteorologische Auswertung grosser Zielrückkehrflüge vergangener Jahre im Alpenraum zeigt, dass weitere Verbesserungen bei der Streckenvorhersage und Flugdurchführung durch die Anwendung statistischer und empirischer Beziehungen möglich sind.

Neuere statistische Ergebnisse und signifikante Beispiele werden herangezogen, um aufzuzeigen, welche synoptischen Lagen für grössere Streckenflüge in welcher Region geeignet sind. Es werden Kriterien zur Wahl des geeigneten Startortes und der dort sich zeitlich ergebenden Thermikvorhersage genannt. Ebenso werden Verfahren zur Vorhersage der wesentlichen meteorologischen Parameter für Flugplanung und -durchführung, wie z.B. Einsetzen, Stärke und Andauer der thermischen Entwicklung und die Höhe der Wolkenbasis im Tagesverlauf mitgeteilt.

5. Conclusions

The statistical results with regard to the height of the cloud base and the mean vertical velocities as function of time will allow us to plan more easily and especially more systematically long-distance flights in the northern part of the Alps.

The given frequencies of different types of thermals in the sub-cloud layer and their horizontal gradients give us a good chance for an appropriate determination of the optimum wing loading.

Furthermore a number of examples of particularly "non-typical" meteorological situations has shown that contrary to earlier statistics a good chance for successful long-distance flights is existing more often.

In future we will have to focus our attention especially on the meteorological navigation in the southern part of the Alps, because until now only insufficient data of this area are available, although there are the best possibilities for long-distance soaring flights.

Literatur

1. *Leykauf, H.*, Meteorologische Aspekte des alpinen Langstreckensegelfluges. Alpine Meteorologische Tagung, Sept. 1980, Aix les Bains, France.
2. *Kreipl, M.*, Meteorologische Statistik als Hilfe zum Streckenflug, Aerokurier, Mai 1978, pp. 490–495.
3. *Kreipl, M.*, Wolken, Wind und Wellenflug, Motor-Sport-Verlag, Stuttgart, 1979.
4. *Vaillant, R.*, Prévision des Vitesses ascendantes des Planeurs en Convection thermique de Plaine, La météorologie, VIe série No 10, Sept. 1977.
5. *Pirker, H.*, Some Computer Calculations on the Optimum Waterballast of Sailplanes, XV. OSTIV-Publ. XIV, Räysklä, 1976.
6. *Konovalov, D.A.*, On the Structure of Thermals, OSTIV-Publ. XI, Alpine, USA, 1970.
7. *Konovalov, D.A.*, Thermals in the Sub-Cloud layer of the Atmosphere, OSTIV-Publ. XIV, Räyskälä, 1976.
8. *Estival, A.*, Some Characteristics of the Convective Layer, OSTIV-Publ. XIV, Räyskälä, 1976.
9. *Trimmel, H.*, Meteorologisch-statistische Auswertung von Streckenflügen, Flugsportzeitung, 1/1978, pp. 19–22.