The Met.Office

Forecasting Notes for Glider Operations

Notes written by HT Brookes
Forecast templates produced by WJD Tucker

February 1997

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CONTENTS

ANNEXES

1. Introduction

These notes are aimed chiefly at forecasters who are required to produce gliding forecasts. It is a practical guide which will help forecasters produce an accurate forecast, not only for local flying but also for the more-demanding cross-country flying.

The notes are split into two parts.

Part 1 deals with aspects of glider operations together with some questions often asked by glider pilots. It also contains a list of favourable and unfavourable soaring areas with respect to weather.

Part 2, titled 'Forecasting Notes', is based on a flow diagram. This flow diagram (Fig. 10) shows in a logical way how to produce a gliding forecast from scratch. Each box in the diagram is dealt with separately and some subjects are backed up by various graphs and diagrams.

For more-detailed studies of meteorology and gliding the following publications are recommended:

- *Handbook of meteorological forecasting for soaring flight* — Technical Note number 158. published by the World Meteorological Organization, 1993.
- *Meteorology and flight*, by Tom Bradbury, published by A&C Black 1989.
- *Meteorology for glider pilots*, by CE Wallington.

2. Glider operations and pilots' questions

Here are some facts about gliding that may be informative, and some answers to questions that glider pilots often ask.

- Gliders can fly long distances (500 km or more) in good soaring conditions and can reach average speeds of over 100 k.p.h. Most cross-country flights take a triangular course and begin and end at the same place.
- The 'soaring season' is generally from late March to mid-September. During autumn, a number of gliding clubs have expeditions to sites favourable for soaring in lee waves. The more-popular sites are in eastern Scotland (Aboyne, near Aberdeen), in mid-Wales and east of the Pennines.
- If the weather is non-soarable, pilots may fly locally, normally up to 2,000 ft.
- Some airspace, such as the London CTR (Control Zone), is unavailable to gliders. There are a number of restricted areas in the UK; Air Traffic Control Services will be able to advise on their locations.
- The vertical-speed indicator (variometer) in a glider is usually calibrated in knots in the United Kingdom. This is a unit glider pilots understand and therefore is preferred when referring to thermal strengths and vertical velocities in mountain waves (1 kn ≅ 100 f.p.m.). The glider sink-rate is normally about 1 knot. Therefore it should be made known that the vertical speeds used in forecasts are air-mass rates as opposed to that read on the variometer.
- With winds of more than 20 kn, it is difficult to make headway when flying cross-country. Thermals tend to get very broken and difficult to use unless there is cloud streeting.
- If gliders are flying cross-country, the height band will usually be between 2,000 ft and the top of dry thermals, i.e. the CU base. However, some experienced pilots will fly in cloud, especially during competitions.
- An outlook for the following day is often asked for.
- If the weather is soarable, glider pilots will often ask where the best conditions will be for cross-country flying.
- Pilots will not fly in precipitation unless they have to. Normally there is no lift, visibility is poor and the glider's performance is degraded.

- Pilots often point out that the visibility at flying levels was worse than the forecast meteorological visibility. This usually occurs when the air is hazy and stable with an inversion just above the flying level. In hazy conditions, visibility into the sun at flying levels and slant visibility can be much worse than the reported meteorological visibility. The most prone wind direction for hazy conditions is from the south-east when air is transported from the continent.

- Pilots wish to know mainly:
  - (a) when convection will begin;
  - (b) when convection will cease;
  - (c) if heating will be cut off by high or medium cloud encroaching;
  - (d) how high the thermals will extend;
  - (e) the area where thermals will occur;
  - (f) the strength of the thermals;
  - (g) if showers or thunderstorms will develop;
  - (h) if CU is likely to spread out into SC;
  - (i) if there is any likelihood of sea air spreading inland.

3. Areas favourable for soaring

- Areas where CU bases are forecast to be highest (often hilly or well drained chalky soil).
- Areas where there is little or no cloud forecast other than CU.
- Areas unaffected by sea-breeze development.
- Areas unaffected by the encroachment of sea air.
- Areas where visibility is good (20 km or more).
- Areas where the wind speed in the convective layer is less than 15 kn.
- Areas of low humidity. This implies high CU bases and good visibility.
- Areas where no precipitation has fallen in the last 24 hours.

4. Areas unfavourable for soaring

- Areas where there is 5/8 or more SC, or 6/8 or more AC or CI.
- Areas where CU is forecast to spread out into SC.
- Areas influenced by sea breezes.
- Areas affected by sea air.
- Areas of high humidity. This implies low CU bases and perhaps poor visibility.
- Areas of poor visibility (less than 8 km).
- Areas where CU will not develop. Although blue thermals may be present, they will be difficult to find.
- Areas where the wind speed in the convective layer is 20 kn or more.
- Areas where the ground is damp or wet.

5. Forecasting notes

The following notes should be used in conjunction with the flow chart. Each box on the flow chart is considered separately.

(a) Analyse charts, tephigrams, etc.

Here are some important points for upper-air and surface chart analysis.

- Wind speed in the convective layer. Penetrating into winds greater than around 20 kn is difficult when thermalling as the glider will perhaps drift backwards. Strong winds distort thermals and make them difficult to use unless the clouds are tending to 'street'.

- The movement of fronts and troughs and their associated cloud. This will affect the development, if any, of thermals.
- Dew-point analysis. Good cross-country soaring days are those with a cloud base of at least 4,000 ft by noon or early afternoon. This means that the air temperature and dew point must be well separated. The difference between the maximum temperature and the afternoon dew point is more than 10 °C on good days.
- The effects of land track and shelter. The size of CU depends on the depth of the unstable layer but the amount depends on how moist the air is. Coastal regions tend to have more cloud with lower bases than areas well inland. The longer the land track the better conditions become. A range of hills is very effective in drying out the moist air from the sea.
- Horizontal advection of temperature and humidity. If cold advection is occurring at low levels the heat required to maintain a dry adiabatic lapse rate is less, hence thermal activity will continue longer.
- Tephigrams should be analysed in the usual way. As a general rule, the larger the area between the environment curve and the dry adiabat at maximum heating, the stronger the thermals will be. To put it another way, the higher a thermal can rise the stronger it will be. Some examples of analysed tephigrams are shown in Figs 1 to 5.

(b) Draw a heating curve, modify tephigram

From the modified tephigram and any other information available *hand* draw a heating curve (computer-produced heating curves can be misleading), taking into account that the temperature rise will be retarded until any dew has been evaporated. From this curve a 'top of thermal' graph can be derived. The tops of thermals can then be predicted for any time of the day. It is important to realize that a superadiabat of up to 2½ degrees can occur on warm, sunny days and this should be taken into account when drawing constructions on a tephigram. An example of a heating curve, with notes on its construction, can be found at Fig. 6.

(c) Any cloud forecast?

Use an appropriate modified tephigram for this. Also look at surface charts and satellite pictures, note any advective changes and how this is likely to affect gliding conditions.

(d) Any CU? (Y)

Tephigram analysis should answer this question. The dew point may change during the day through advection and mixing. As a reference the dew point at sunrise (minimum temperature) should be selected.

(e) Start time, amount, base, top, streets

Use the modified tephigram and the heating curve. The start time is normally recognized to be when a dry adiabat (thermal) can rise to 2,000 ft. The amount will depend on the moisture content of the convective layer. Thermals will begin to decrease about an hour after maximum temperature has been reached and usually subside quickly after 1700 UTC.

Cloud streets enable a pilot to achieve high cross-country speed by flying along and beneath them, rather than circling in thermals.

Requirements for the development of cloud streets are:

- fresh winds near the ground;
- wind direction nearly constant with height in the convective layer;
- an inversion or stable layer to limit the depth of instability, normally at a height of around 6,000 ft;
- the wind has a constant direction with height in the convective layer and the speed reaches a maximum in the middle of the layer.

(f) Any other cloud or risk of spread-out?

- The effect of upper cloud.

Thin CI makes thermals weaker. Thickening CS ahead of a warm front or trough arriving before the ground has warmed up often prevents any thermals forming unless the air is very unstable. CS which arrives during the afternoon will reduce thermal strength but only stops them altogether if they were shallow and weak in the first place. AS nearly always brings thermal activity to an end. However, despite a sheet of AS, weak thermals may occur when the air is very unstable and the ground has already become warm.

- Spreading out of CU to form SC.

This is one of the most common reasons for a spoilt soaring day. It usually occurs when:

- there is an inversion which keeps all the CU tops down to the same level;
- the air below the inversion is very unstable (so that CU forms with very little heating);
- it is very moist, so that the base of the cloud is at least 2,000 ft below the inversion.

If the cloud sheet cuts off the sun completely the thermals usually die out. Then the absence of thermals to maintain the cloud results in the sheet eventually breaking up. However, soon after the sun has broken through the thermals will begin again and carry more moisture aloft thus rebuilding the cloud sheet. Glider pilots often refer to this phenomenon as 'cycling'.

(g) Adjust thermal strength accordingly

This means reducing thermal strength! A solid sheet of SC or AS will nearly always prevent thermals from forming unless the air is very unstable.

(h) Thermal strength

As a general rule thermals are classified as:

- weak with a vertical speed of 1–2 kn
- moderate with a vertical speed of 3–5 kn
- strong with a vertical speed of ≥6 kn

A nomogram is provided (Fig. 7) to help you assess thermal strength. It was constructed using reports from French glider pilots and seems to work quite well in central and southern England.

Another way of assessing thermal strength is presented below. The general principle is that the greater the height to which a thermal column rises, the faster the rate of climb will be.

	Max. height of dry adiabatic lapse rate	Mean rate of climb (air mass)
Cloudless thermals	3,000 ft	3 kn
	5,000 ft	5 kn
	7,000 ft	6 kn
Cloud-capped thermals (with small CU)	3,000 ft	4 kn
	5,000 ft	6 kn
	7,000 ft	7 kn
Cloud-capped thermals with cold advection occurring	3,000 ft	5 kn
	5,000 ft	7 kn
	7,000 ft	9 kn

(i) Any CU? (N)
Consider other cloud or clear skies.

(j) Height, type, amount of other clouds
If there are no thermals pilots may want to fly locally (normally up to 2,000 ft), and therefore will require cloud information.

(k) Blue thermals?
Blue thermals are cloudless thermals and are weaker than cloud-capped thermals. As a blue thermal has no 'marker' cloud they are difficult to find! However, they are eminently useful for local soaring and indeed glider pilots fly cross-country on 'blue' days when they randomly find the thermals. Thermals can also form into 'blue' streets.

(l) Top of thermal and strength
The top of a blue thermal will occur where a dry adiabat at a particular temperature intersects the environment curve on a tephigram. The strength can be obtained from the table above or from the nomogram.

(m) Any mountain waves?
Mountain waves are covered in detail in a number of books and papers. For the purpose of these notes it is sufficient to say that the basic conditions for wave formation are:

- a wind speed of at least 15 kn blowing nearly at right-angles to the ridge;
- an inversion or stable layer not far above the ridge top with a deep layer of less-stable air above it;
- an increase in wind speed with height, but the direction should remain fairly constant.

The only ready guide available is the 'Casswell method' of prediction. This should be used with caution as it treats the troposphere in two smoothed layers, dealing with almost its entire depth. It can 'miss' shallow waves which can occur in a very limited depth. An example of a tephigram which produced strong mountain waves is at Fig. 8.

(n) Strength, height band
The Casswell method gives a maximum vertical speed and its associated height. Glider pilots will want to know if they can contact the wave perhaps through thermalling or by being towed to the base of the wave updraught. Pilots will also want to know how high they can climb, i.e. the top of the wave. This is very difficult to forecast! A subjective look at a tephigram is the only answer, where the base of an inversion or isothermal layer will suggest the lowest level of wave activity if all other parameters are favourable to development.

(o) Winds
Winds at surface, 2,000 ft, 5,000 ft, and 10,000 ft and associated temperatures are sufficient except when mountain-wave activity is forecast above 10,000 ft. Surface wind is important — gliders are prone to damage in windy conditions and will always opt to take off into wind.

Glider pilots use ridges for soaring if the wind is in a favourable direction. The best direction is at right-angles to the ridge but a variation of as much as 40 degrees may occur before the slopes cease to be soarable. The speed should be within a range of 15 to 40 kn. At a number of gliding sites in the UK a slope is the main source of updraught for local flying.

(p) Sea breeze, arrival time, encroachment of sea air
Sea breezes are important to glider pilots because the air on the seaward side of the sea-breeze front is stable and therefore unusable for soaring. Sea breezes and their effects have been written about in great detail elsewhere. For the purposes of these notes, conditions for sea-breeze development are:

- land temperature greater than sea temperature;
- convection to between 4,000 ft and 10,000 ft;
- a light off-shore component of airflow during the morning. A 3,000 ft wind of less than 15 kn is suggested. No sea breeze is likely if there is already an on-shore component in the morning.

A nomogram for the arrival time is at Fig. 9.

Cool, stable sea air can be advected inland with the right wind direction and can penetrate many miles inland. This is a common occurrence in the Bristol Channel area with a south-westerly wind, and near to The Wash with a north-easterly wind. Sea air kills off all thermals. The sea-breeze front itself provides good soaring conditions as it moves inland.

(q) Visibility
Normal meteorological visibility is required. A layer of thick haze may occur just below the inversion (top of the convective layer), especially in air originating from the continent. Visibility into the sun in this layer may be much worse than elsewhere.

(r) Weather
Although pilots are interested in all weather types, the following are of particular importance to glider pilots as they can be hazardous to operations.

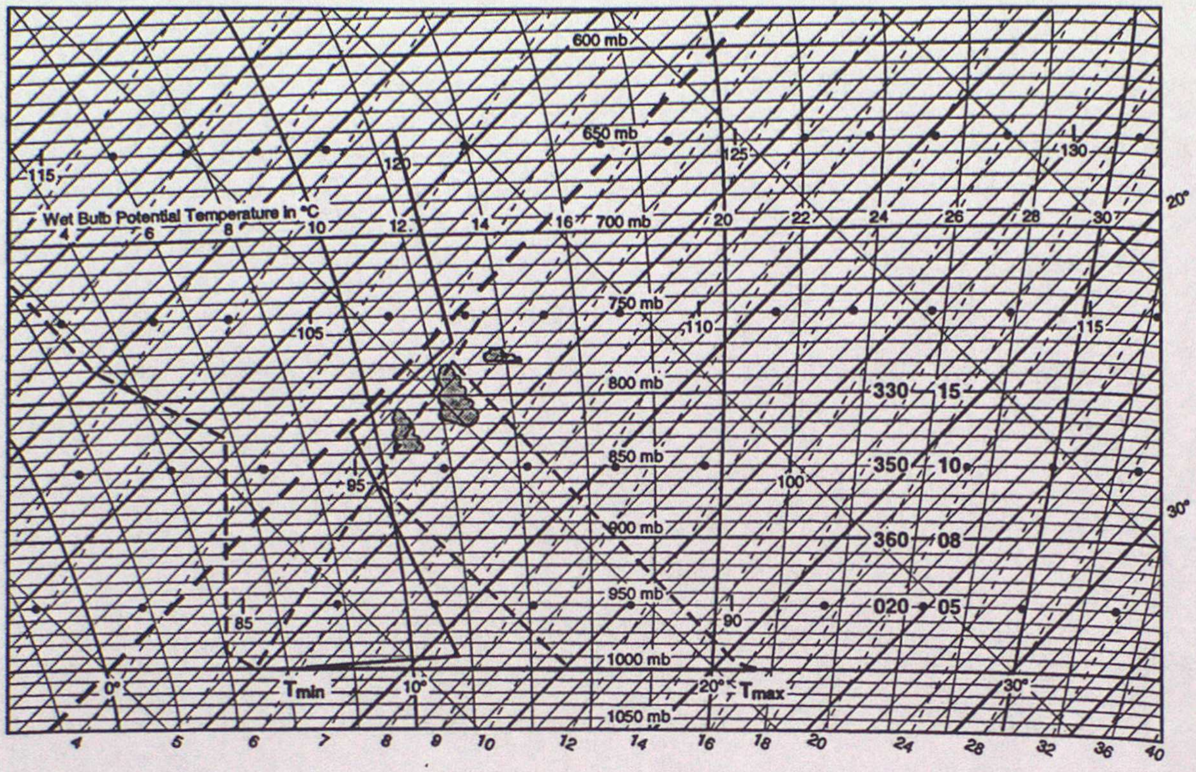
- Haze. This increases the risk of collision, especially when there are a number of gliders in one thermal. Looking into sun dramatically cuts down visibility.
- Heavy showers/thunderstorms. These can produce severe turbulence, strong downdraughts and rapidly changing winds (apart from washing out any thermal activity). The turbulence could damage the glider or even make it break up in flight. Strong downdraughts can put a glider on the ground in less than a minute. The variable and gusty surface wind can make landing hazardous. Although lightning can produce static discharges in flight, seriously damaging strikes are rare. However, if the glider is being launched by winch, the winch cable acts as a lightning conductor. This can be dangerous for the pilot and the winch driver.

(s) Freezing level
Most gliders stay clear of cloud and icing conditions. But some pilots elect to fly in cloud in order to gain height over and above what would be possible using dry thermals. The freezing level is then very important. If a glider suffers from icing, the control surfaces may freeze solid. The canopy may ice over, reducing the visibility to nil.

(t) Hazards
All hazards associated with aviation warnings issued as routine by The Met. Office should be considered. Of particular interest are wind shear near the ground and low-level turbulence.

Examples of plotted radiosonde ascents with appropriate analysis and comments

Fig. 1



Good points:

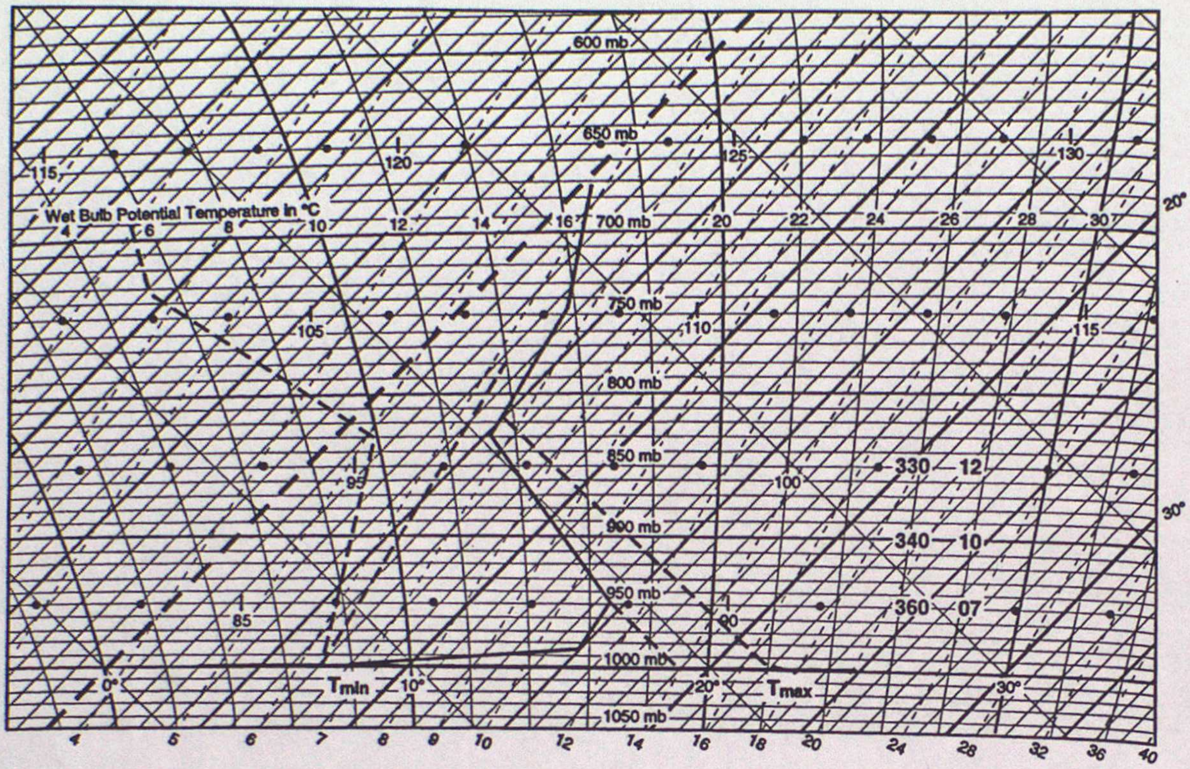
- very high CU base;
- cold advection in the convective layer;
- light wind with a favourable direction (NNW);
- no spread-out into SC;
- early start to thermal activity.

Bad points:

- nil.

Average thermal strength 6–8 kn.

Fig. 2



Good points:

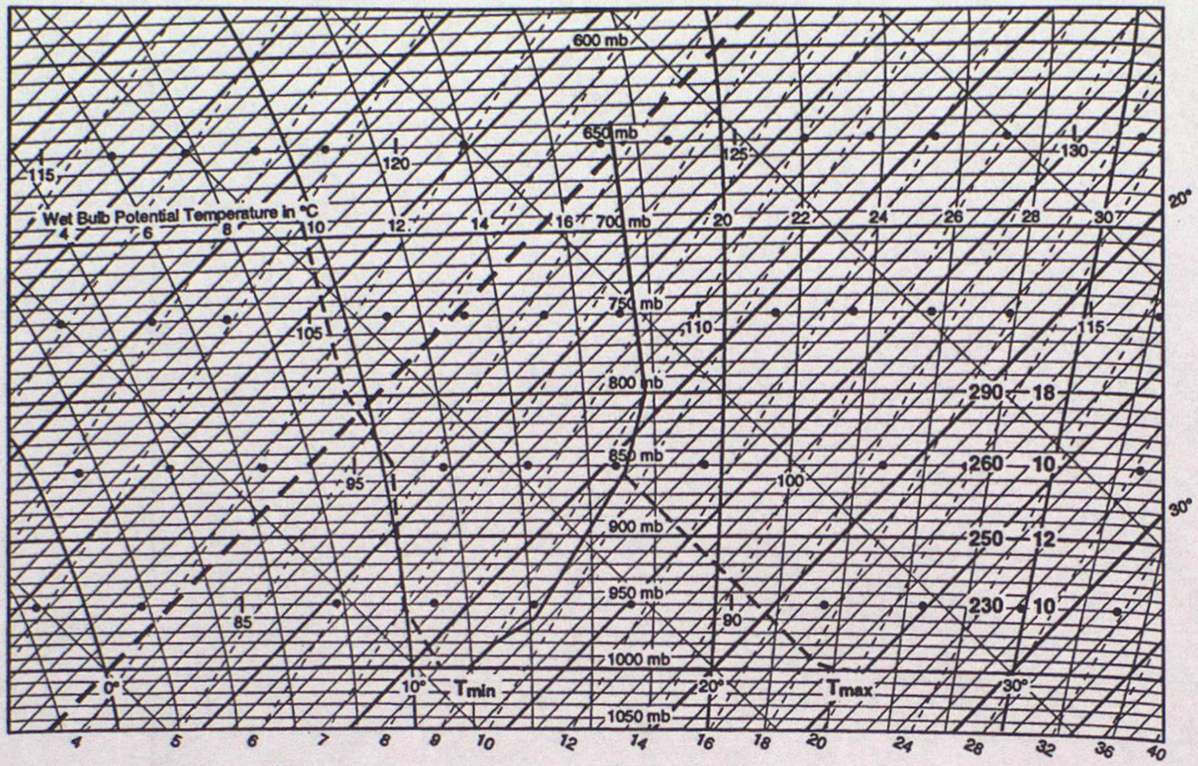
- dry adiabat to 6,000 ft;
- cold advection in the convective layer;
- light wind with a favourable direction (NW);
- dry above the inversion.

Bad points:

- late start to thermal activity;
- mainly 'blue' thermals.

Average thermal strength 4 kn but 6 kn around maximum heating time.

Fig. 3



Good points:

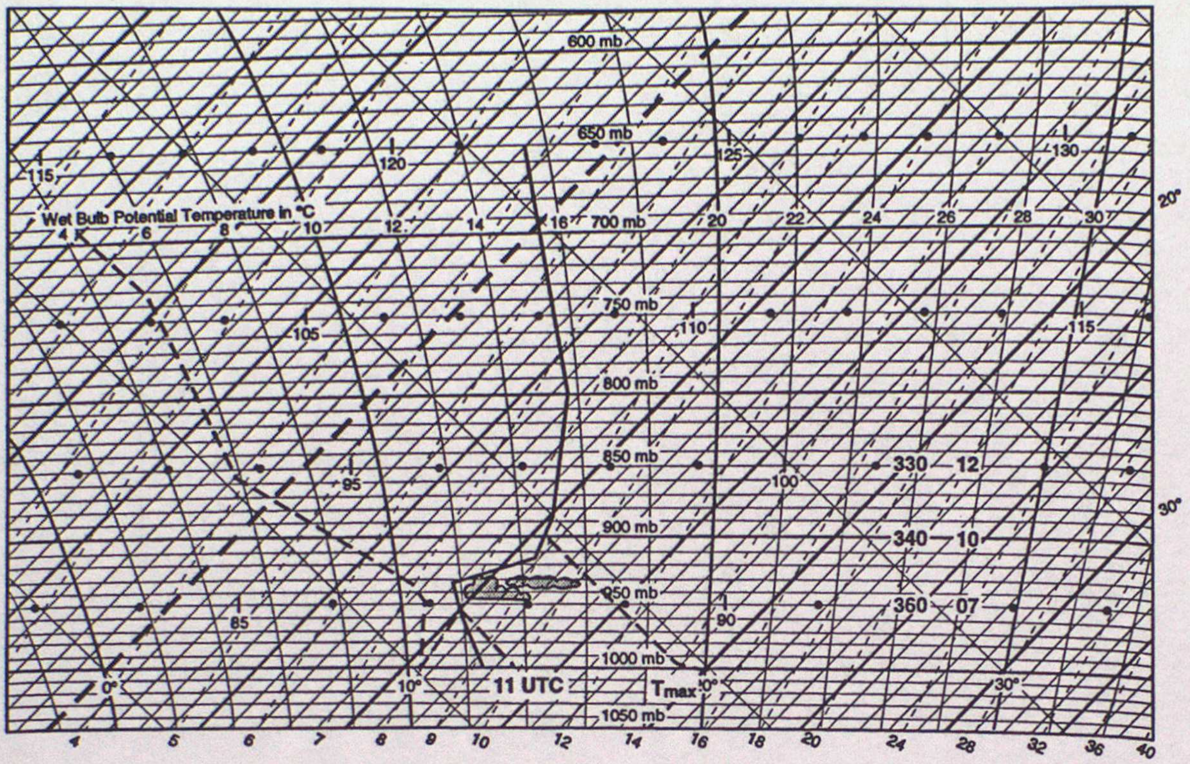
- dry adiabat to 5,000 ft at maximum heating time;
- light winds.

Bad points:

- isothermal in the convective layer;
- generally a bad wind direction (SW);
- 'blue', i.e. cloudless, thermals;
- latish start to thermals;
- warm advection in the convective layer.

Thermal strength slowly increasing to a maximum of 3 kn.

Fig. 4



Good points:

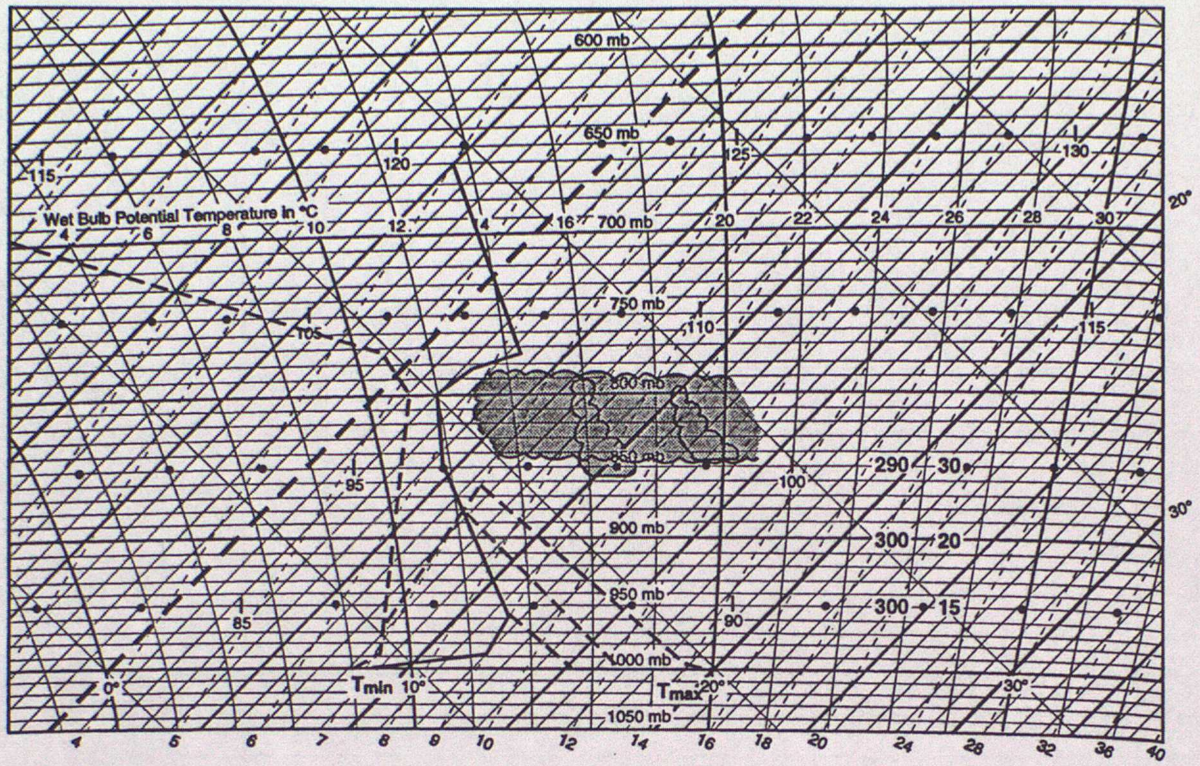
- light winds and a generally favourable direction (NW);
- any SC dispersing;
- dry above the inversion;
- cold advection in the convective layer.

Bad points:

- low cloud base;
- any morning CU dispersing;
- 'blue' thermals in the afternoon;
- weak thermals.

Average thermal strength 1–2 kn.

Fig. 5



Good points:

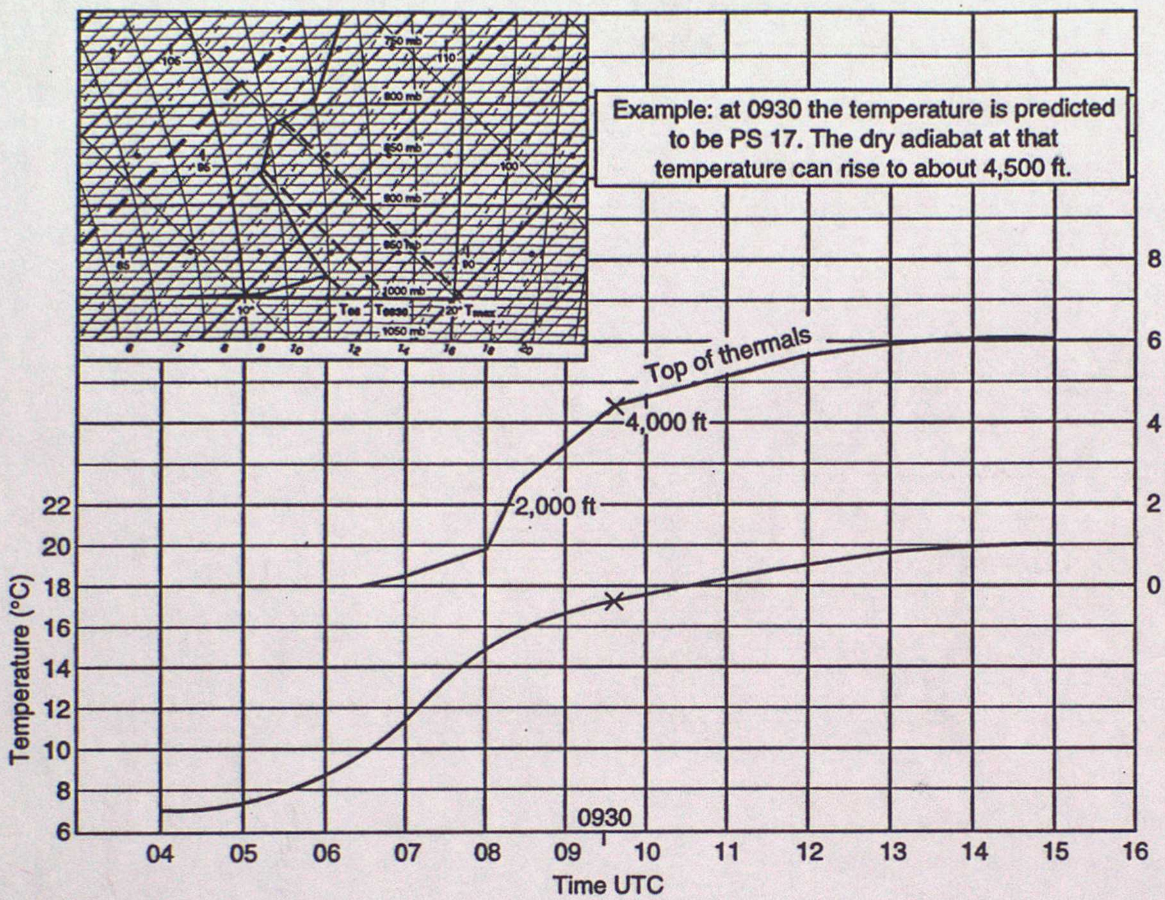
- high CU base at maximum temperature.

Bad points:

- CU spreading out into SC;
- thermals will start quite late in the day;
- the winds are strong.

Average thermal strength 3 kn becoming 0–2 kn as the CU spreads out into SC.

Fig. 6



Example: at 0930 the temperature is predicted to be PS 17. The dry adiabat at that temperature can rise to about 4,500 ft.
Top of thermals
4,000 ft
2,000 ft
0930
Temperature (°C)
22
20
18
16
14
12
10
8
6
DALR
8
6
4
2
0
04
05
06
07
08
09
10
11
12
13
14
15
16
Time UTC

Fig. 7

Nomogram for determining thermal strength

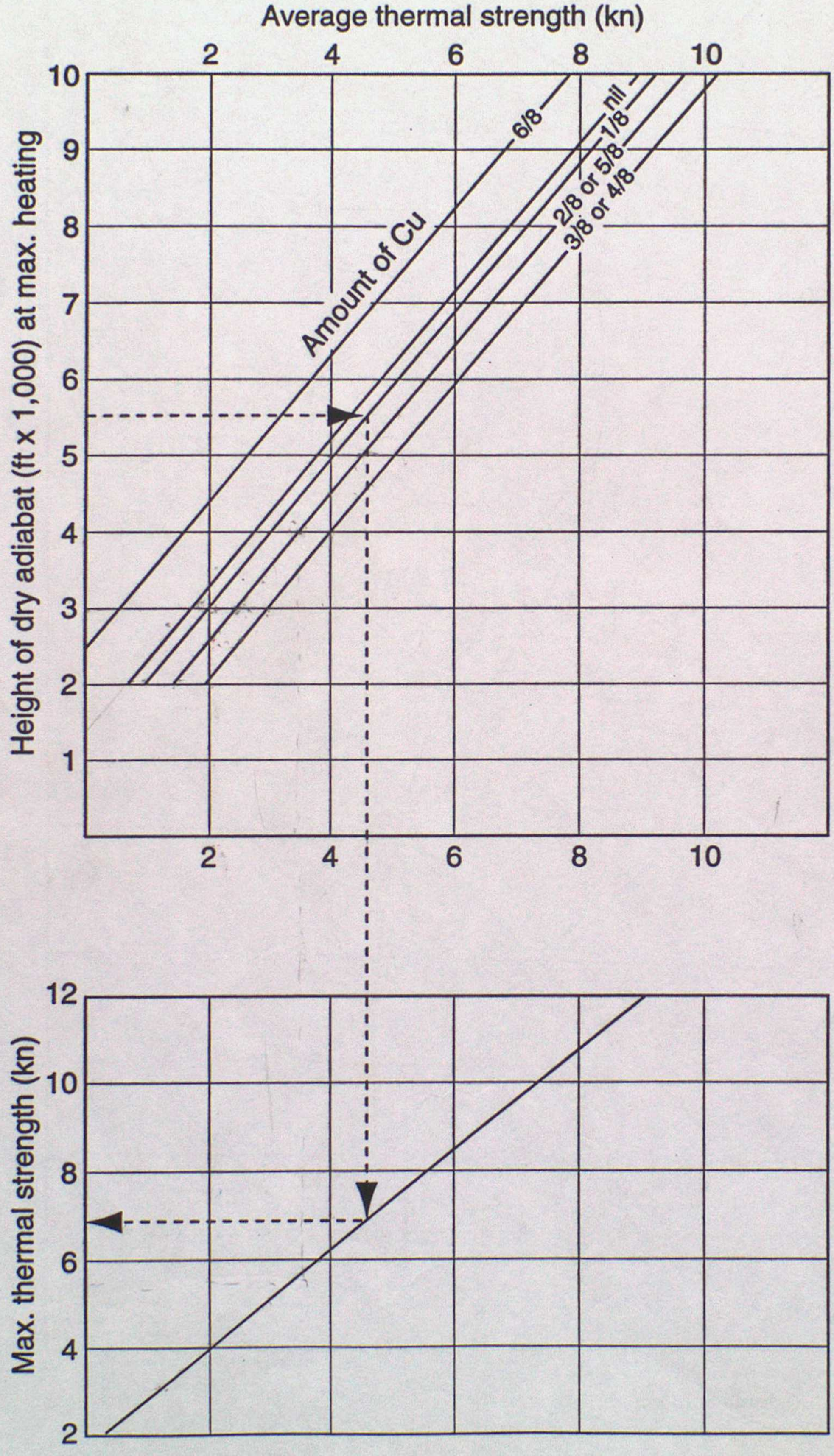
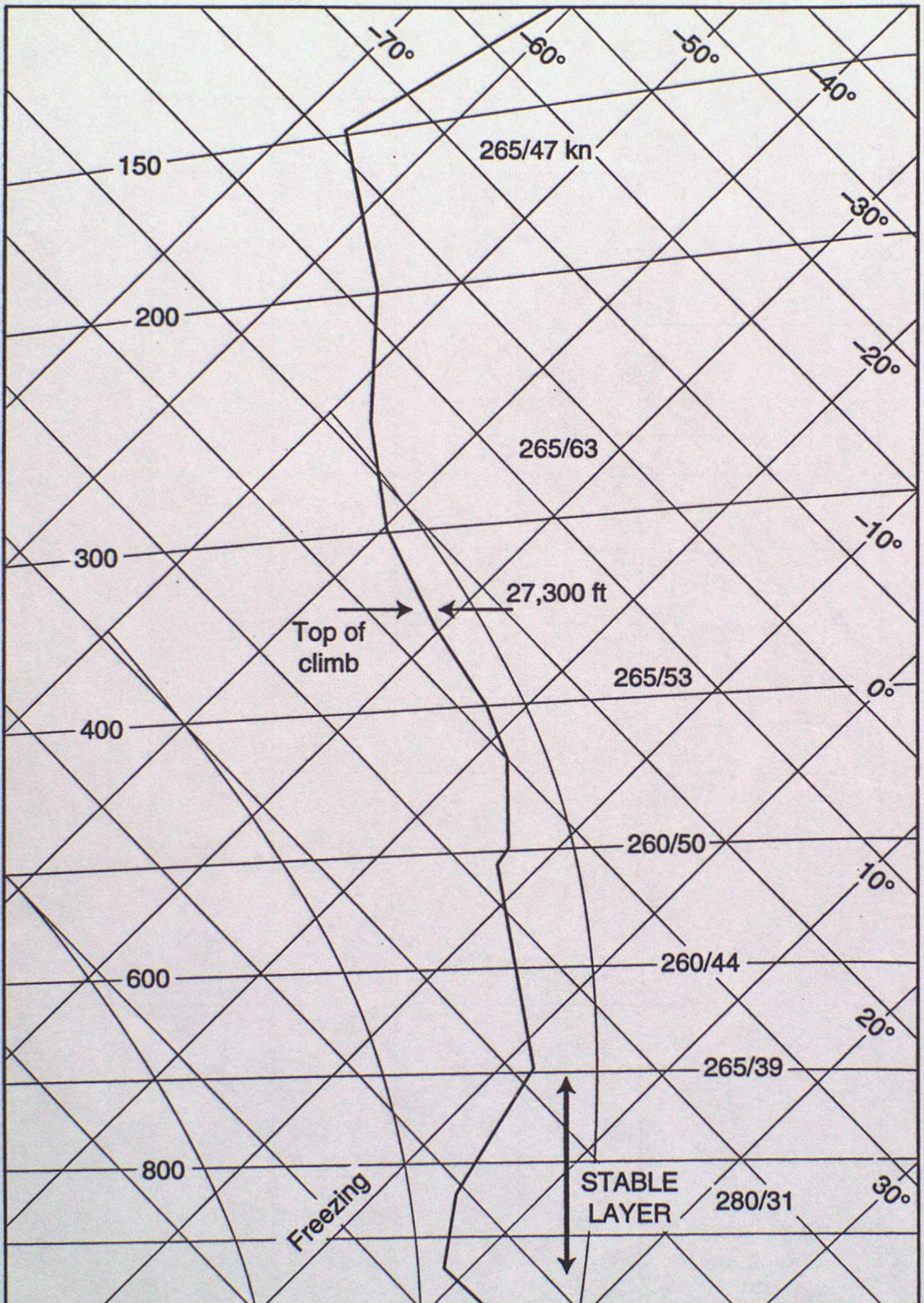
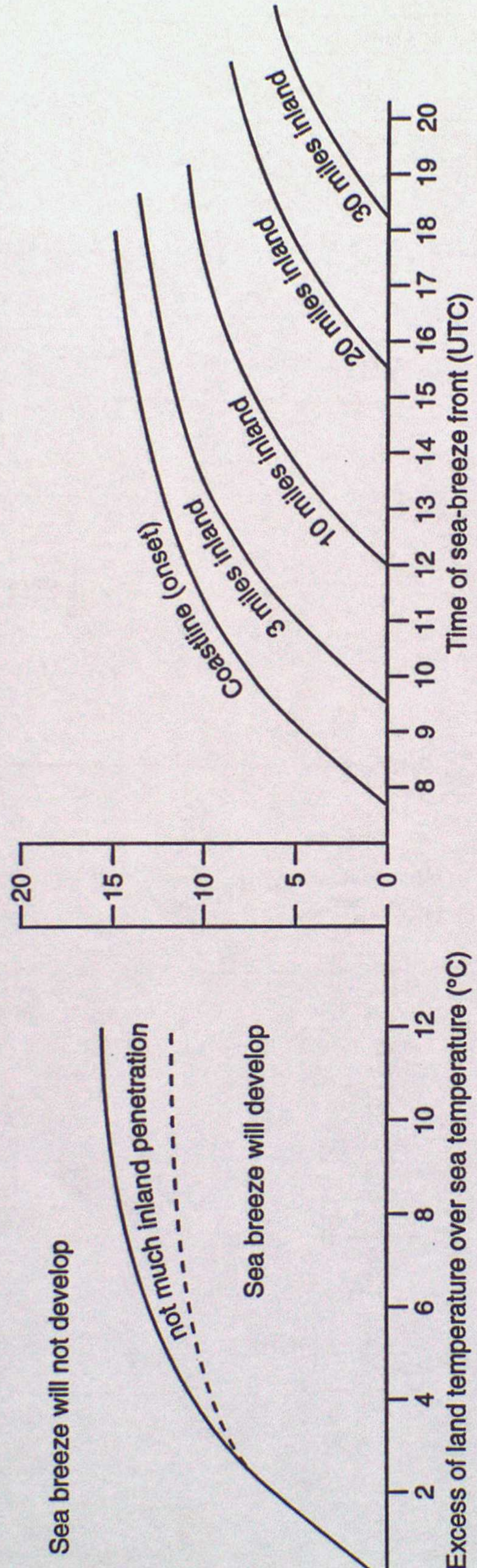


Fig. 8



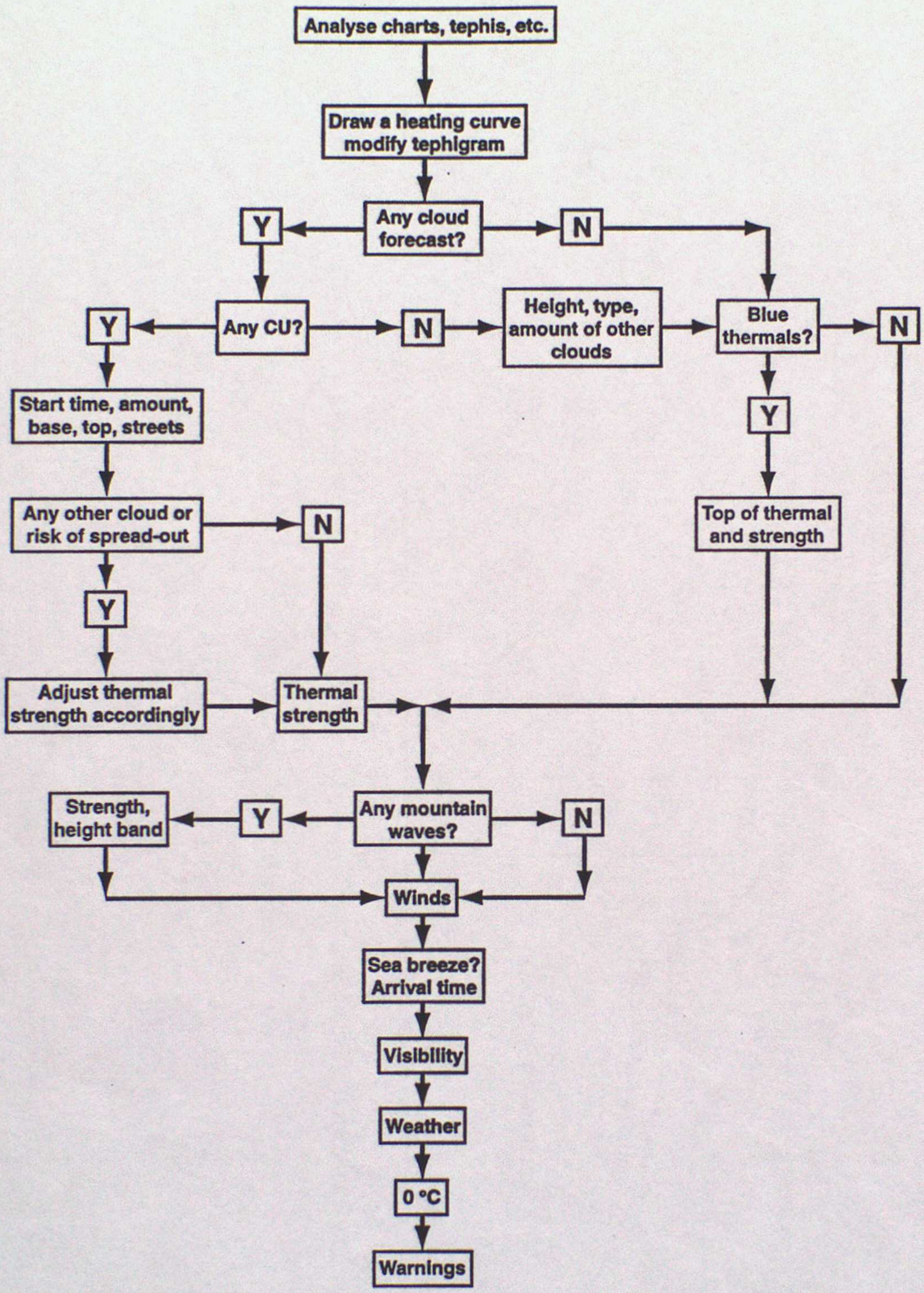
An ascent which produced strong mountain waves
A glider flew to 27,300 ft to the lee of the mountains of North Wales

Fig. 9



Sea-breeze development

Fig. 10 Flow chart for preparing a gliding forecast



Forecast Weather for Gliding (below 10000 FT) at 1300 UTC on

WEATHER SYMBOLS:

MOD/SEV TURBULENCE
MOD/SEV ICING
HAIL
THUNDERSTORM
[/CB IMPLIES]
FREEZING PRECIPITATION [IMPLIES]
0 C: SPOT VALUE OF HEIGHT OF 0 C

Sea air

Thermals:
Strength KT
Start time UTC UTC

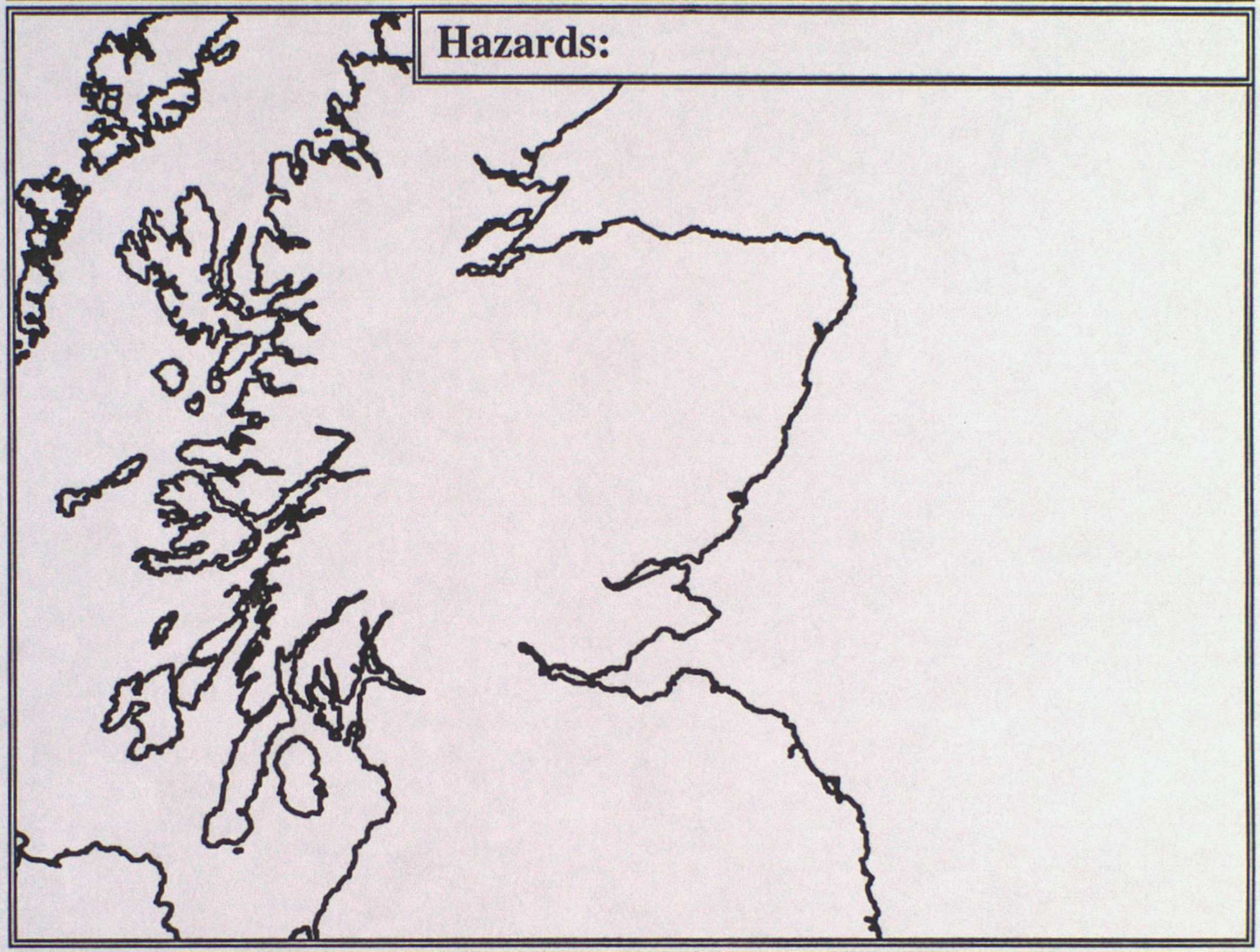
Lee Waves

Fronts/zones moving as shown by arrows
Speed in knots

Winds/Temps at 2000 FT AMSL
e.g PS06

All heights in 100s FT AMSL.
eg.TOP 5000 FT = 050
BASE 2500 FT 025
(XXX means height above 10000 FT AMSL)

Hazards:



No. Issued at UTC by The Met. Office. Forecaster:

WEATHER SYMBOLS:

MOD/SEV TURBULENCE

MOD/SEV ICING

HAIL

THUNDERSTORM

[/CB IMPLIES]

FREEZING PRECIPITATION [IMPLIES]

0 C:	SPOT VALUE OF HEIGHT OF 0 C

Sea air

Thermals:

Strength — KT

Start time UTC — UTC

Lee Waves

Fronts/zones moving as shown by arrows Speed in knots

Winds/Temps at 2000 FT AMSL

e.g PS06

All heights in 100s FT AMSL.

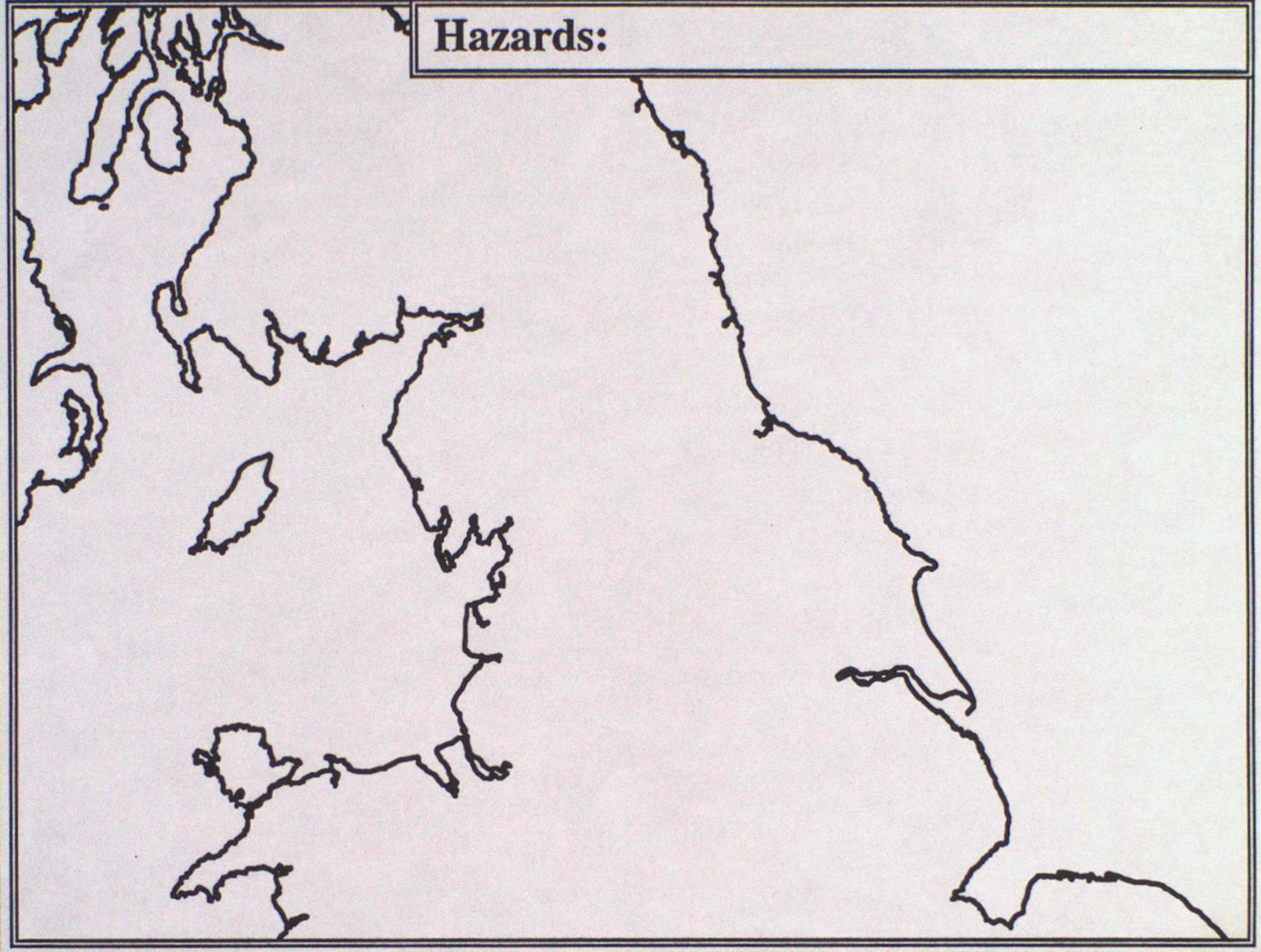
eg.TOP 5000 FT = 050

BASE 2500 FT 025

(XXX means height above 10000 FT AMSL)

Forecast Weather for Gliding (below 10000 FT) at 1300 UTC on

Hazards:



No. Issued at UTC by The Met. Office. Forecaster:

WEATHER SYMBOLS:

MOD/SEV TURBULENCE

MOD/SEV ICING

HAIL

THUNDERSTORM

[/CB IMPLIES]

FREEZING PRECIPITATION
[IMPLIES]

0 C: SPOT VALUE OF HEIGHT OF 0 C

Sea air

Thermals:
Strength KT
Start time UTC UTC

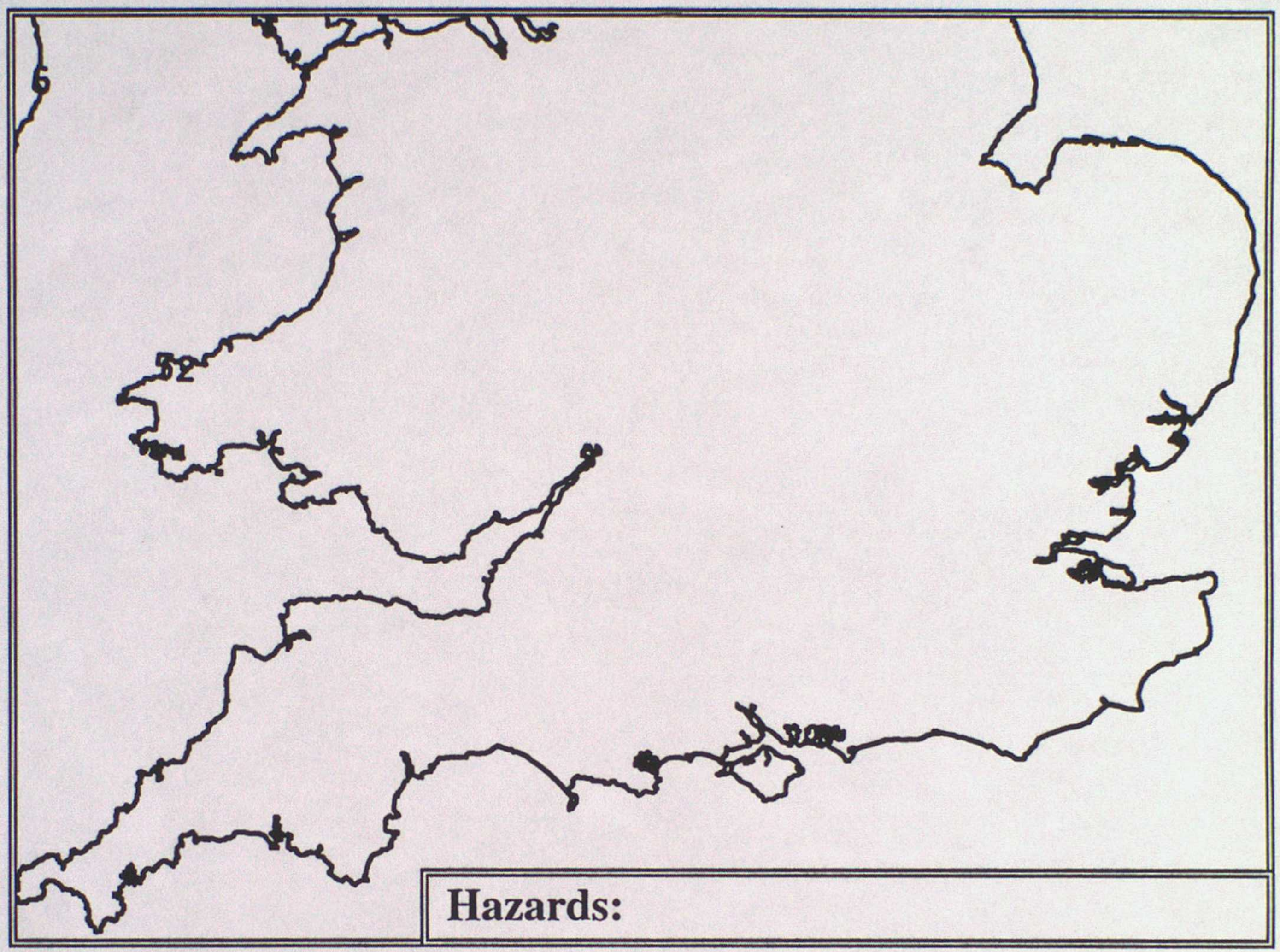
Lee Waves

Fronts/zones moving
as shown by arrows
Speed in knots

Winds/Temps
at 2000 FT AMSL
e.g PS06

All heights in 100s FT AMSL.
eg.TOP 5000 FT = 050
BASE 2500 FT 025
(XXX means height above 10000 FT AMSL)

Forecast Weather for Gliding (below 10000 FT) at 1300 UTC on



Hazards:

No. Issued at UTC by The Met. Office. Forecaster:

Forecast Weather for Gliding (below 10000 FT) at 1300 UTC on 20 Mar 97

WEATHER SYMBOLS:

- MOD/SEV TURBULENCE
- MOD/SEV ICING
- HAIL
- THUNDERSTORM
- [/CB IMPLIES]
- FREEZING PRECIPITATION [IMPLIES]
- 0 C: SPOT VALUE OF HEIGHT OF 0 C

Sea air:

Thermals(air mass): Strength in KT Start time UTC — KT / UTC

Lee Waves

Fronts/zones moving as shown by arrows Speed in knots

Winds/Temps at 2000 FT AMSL e.g. PS06

Visibility in metres (M) and kilometres (KM)

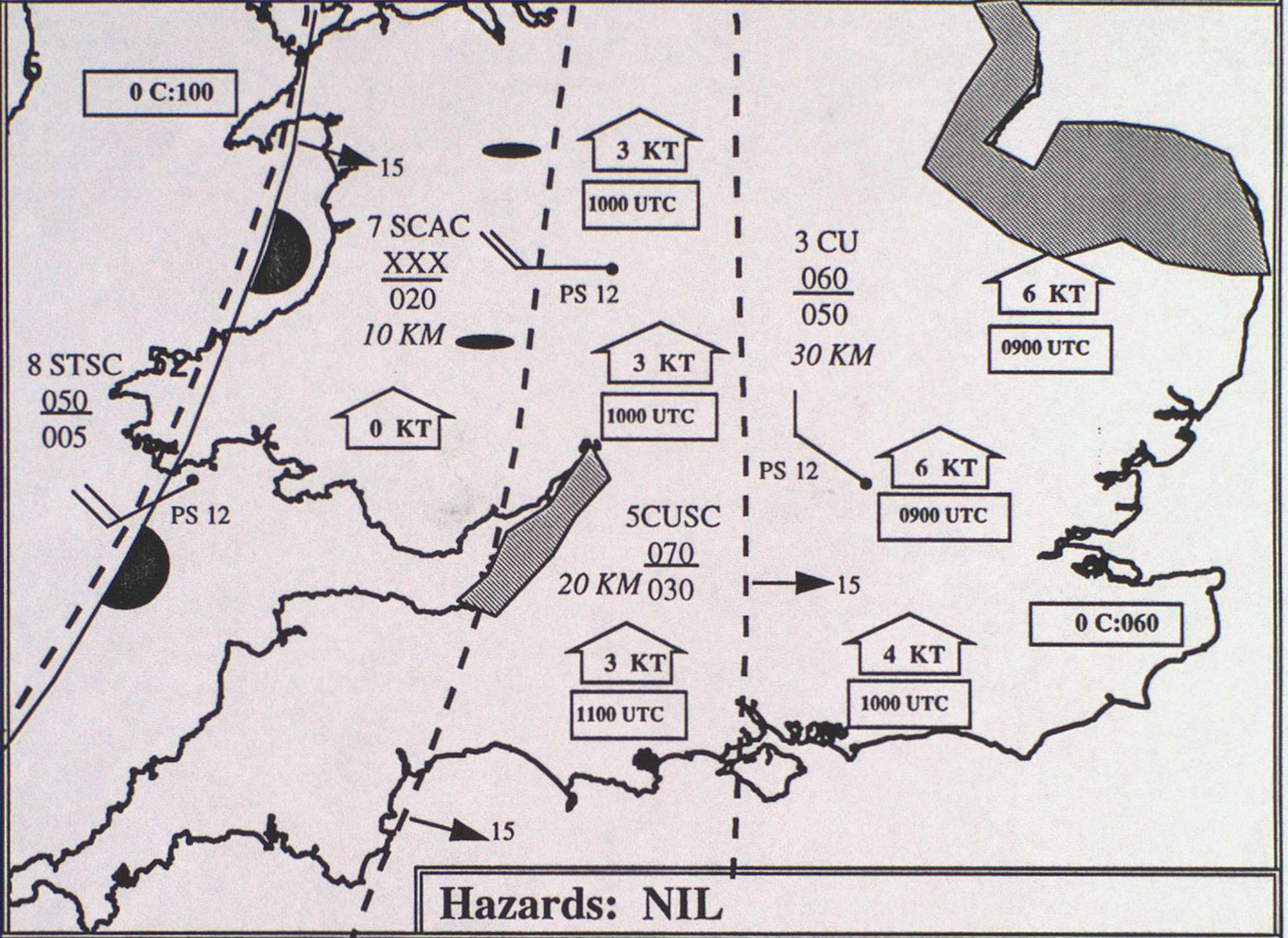
All heights in 100s FT AMSL.

eg. TOP 5000 FT = 050

BASE 2500 FT = 025

(XXX means height above 10000 FT AMSL)

Boundaries marked thus: - - - - - - - -



Hazards: NIL

No. Issued at UTC by The Met .Office. Forecaster:

Gliding Forecast for on

Heights AGL in Feet
Clouds in OKTAs
RH = Relative Humidity (Out of cloud)

General Situation:

24000							
10000							
5000	RH %						RH %
4000							
3000							
2000							
Thermals KT	RH %						RH %
Time UTC	09	11	13	15	17	19	

Visibility:		
WIND	10000 FT	
	5000 FT	
	2000 FT	
	Surface	
Hazards:		MAX Temperature: C

No . Issued by Meteorological Office at UTC. NOT TO BE USED FOR FLIGHT DOCUMENTATION UNLESS UPDATED BY A MET BRIEFING ON EXTN.

Gliding Forecast for on

Heights AGL in Feet
Clouds in OKTAs

General Situation:

24000						
10000						
5000						
4000						
3000						
2000						
Thermals KT						
Time UTC	09	11	13	15	17	19

Visibility:

W	10000 FT	
I	5000 FT	
N	2000 FT	
D	Surface	

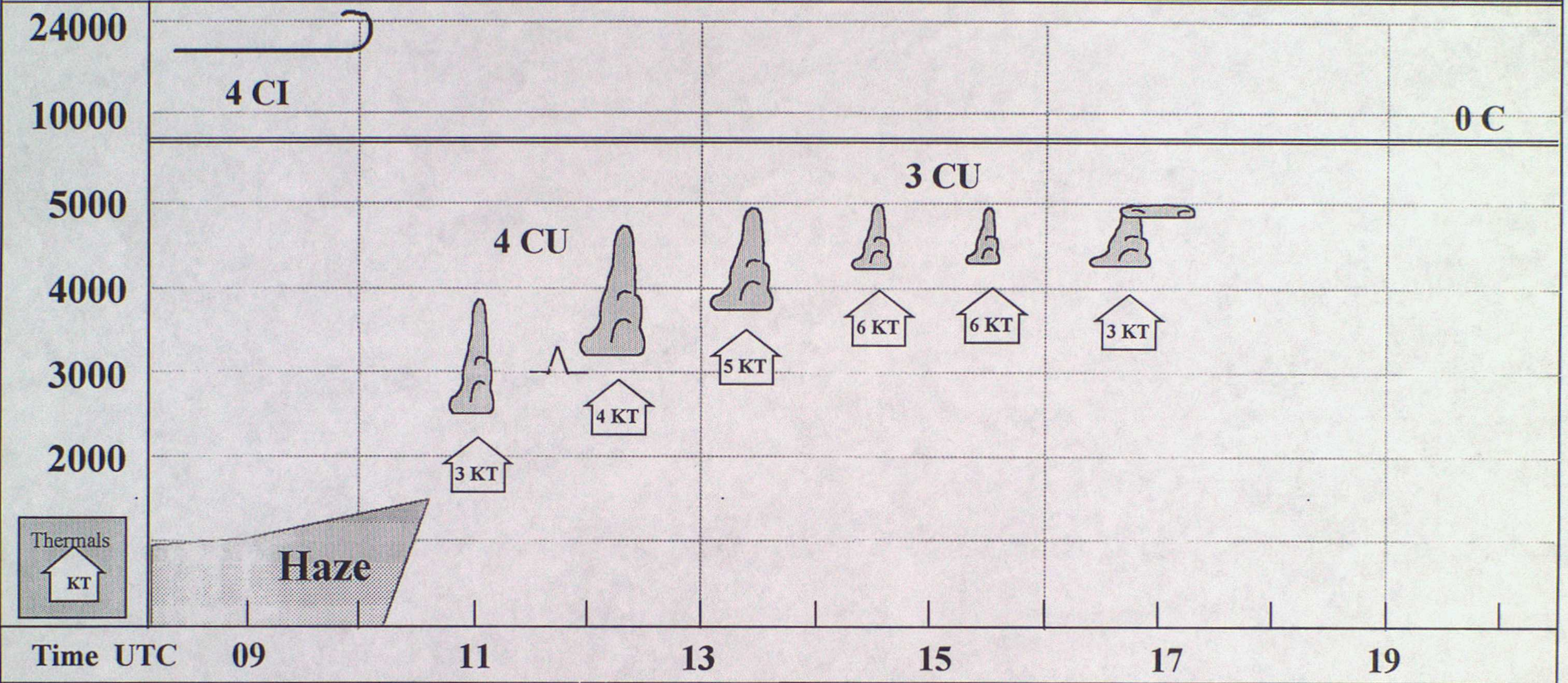
Hazards: MAX Temperature : C

No . Issued by Meteorological Office at UTC. NOT TO BE USED FOR FLIGHT DOCUMENTATION UNLESS UPDATED BY A MET BRIEFING ON EXTN.

Gliding Forecast for Syerston on 18 September 1996

Heights AGL in Feet
Clouds in OKTAs

General Situation: Early haze will soon clear leaving the area under an unstable,westsouthwest, airstream



Visibility:		7 KM BECMG 25 KM
W	10000 FT	250 20 KT
I	5000 FT	250 18 KT
N	2000 FT	260 15 KT
D	Surface	220 05 KT BECMG 240 08 KT
Hazards:		Nil

MAX Temperature: 24 C

No . Issued by Meteorological Office at UTC. NOT TO BE USED FOR FLIGHT DOCUMENTATION UNLESS UPDATED BY A MET BRIEFING ON EXTN.