SOME CHARACTERISTICS OF RADIATION FOG
DEDUCED FROM BALTHUM DATA

by

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Some characteristics of radiation fog deduced from Balthum data

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Introduction

Cardington Balthum data have been used to study the evolution and characteristics of radiation fog, and to indicate the value to forecasters of series of low-level temperature and humidity soundings in fog situations.

1. The data

During fog periods from October 1976 to February 1977 and October 1977 to March 1978 Balthum ascents and descents, additional to the routine soundings, were made at Cardington to provide details of the evolution, structure and physical characteristics of radiation fog. At times the soundings were made at about 2-hour intervals, i.e. the descent reaching the surface about 2 hours after the ascent commenced. Full hourly surface synoptic observations were available from Cardington, as were wind records at heights of 36 m, 10 m, and occasionally at 2 m.

2. Analysis

a) Profiles

From the basic data of twenty-six occasions of fog, nine cases were selected where the large number of soundings made the data amenable to analysis by time-height cross-sections. Plotting of data on these diagrams revealed the topography of the cool and moist fog-bearing layer and its temporal variations. However, it became apparent that discrepancies existed between ascent and descent data in the vicinity of the fog top, which was assumed to be a little way above the base of the nocturnal inversion and below the level at which a dew-point depression was first recorded. Within the fog layer, and well above it, ascent and descent data usually agreed well but the layer between the middle of the inversion layer and the inversion top, i.e. near the fog top, was a region of marked disagreement between the two sets of data. This layer was often 100-200 m in thickness and within it descents indicated a much sharper and larger change of temperature over a shallower layer than did the ascents. The descents indicated warmer air than the ascents and, usually, a larger dew point depression.

The mode of operation of the equipment (Painter, 1970) is such that the balloon-borne instrument package is moved to a new height where it remains for five minutes before readings are taken from the aspirated dry - and wet bulb thermometers. This procedure should nullify errors due to lag in the instruments. The fact that descent temperatures, as they approach the top of an inversion are warmer than in the ascent confirms that instrument lag is not the cause of the discrepancies. Also, the operating procedure should ensure that the dry-bulb element, if wetted during ascent through the fog, has time to dry out before a reading is taken above the fog top.

Because these discrepancies appear only near the fog top a possible explanation is that the bulky and moisture-collecting instrument package becomes thoroughly wetted during ascent through the fog, by direct interception of fog droplets and possibly by condensation, and until it dries out completely the dry-bulb element (though dry itself and associated with a wet bulb depression) may be recording in a moisture - contaminated environment where evaporational cooling may be present in the vicinity of the sensors. Figs 1 and 2 show the Balthum package and the aspiration tubes are evidently drawing air from near the bottom of the package. Most of the suspect temperatures were taken less than ten minutes after the package had emerged from the top of the fog or stratus layer.

Thus, although there may be a reason to suspect the ascent temperatures just above the fog, there is no obvious reason to suspect the descent temperatures in these situations. The package descending in dry air above the fog should yield correct data before and after entering the fog layer. Therefore the descent data are considered to be the more reliable in the situations examined in this study. Some examples of the effects discussed here are shown in Fig. 3 where pairs of ascents and descents indicate the general form and magnitude of the discrepancies. These should be borne in mind when interpreting Figs 4-12.

Some cases have been noted where discrepancies between ascent and descent data appear when no fog or cloud was present, but these cases are few in number and are in situations where time or advective changes could not be ruled out.

It is noteworthy that the heights and temperatures of the bases of nocturnal inversions in fog measured by both ascents and descents agree very well when time changes are taken into account, not only in the examples shown in Fig. 3 but in many other cases examined. The height of the top of the fog, deduced to be at the level where the dew point depression changes from zero above the inversion base agrees less well between ascents and descents.

b) Time - height sections

All Balthum data were plotted on time cross-sections for analysis of bases and tops of inversions, temperature and the topography of the moist layer. The moist layer was defined as the region where the dew-point depression was $<0.5^{\circ}C$ (RH ~ 97%). Full hourly synoptic observations and data on visibility, and wind at 36 m, 10 m (and 2 m when available) were incorporated into the analyses. Upper wind speeds from the Balthum were also included. On some occasions the heights of the fog top as deduced from droplet spectrometer measurements were available, (Caughey, et al, 1978; Brown, 1980). Simplified versions of the analyses are reproduced in Figs 4-12 for each of the nine fogs examined in detail, and are discussed individually.

i) 27 October 1976 (Fig 4) - Fog clearance by insolation

The fog was already present at 00 GMT and the nocturnal inversion had lifted to 50-70 m where it remained until sunrise. The moist layer, initially extending to 100 m, deepened steadily between 02 and 04 GMT. The fog top measured by droplet spectrometer lifted quickly between 03 and 04 GMT. The time and height resolution of the Balthum soundings was not fine enough to show the short period fluctuations of the fog top though the deepening and subsequent decrease in depth of the moist layer was indicated quite well. The fog top averaged about 50 m above the base of the nocturnal inversion. Surface temperatures rose soon after sunrise and the fog became patchy at 09 GMT, revealing 7/8 of stratocumulus at 1350 m, before it cleared and lifted to become broken low stratus cloud. The stratus lifted as the inversion lifted and transformed into small cumulus as the inversion base reached its top and a lapse rate was established throughout the layer by 12 GMT. Fog reformed in the evening by 22 GMT at a temperature of 10°C, the same temperature at which it had cleared by insolation during the morning.

ii) 10-11 November 1976, (Fig 5) - Fog clearance by strengthening wind aloft

With a 10 m surface wind of 6 Kn fog formed from mist in a 150 m deep moist layer, probably as a result of slow cooling within the layer, rather than a shallow fog building upwards from the surface. The first indication of the nocturnal inversion base was at 110 m about one hour after fog formed between 19 and 20 GMT. The inversion base remained level for a few hours then gradually lowered, as did the top of the moist layer, with previously - steady surface temperature beginning to decrease at 1°C/hr after about 23 GMT. The base of the inversion reached the surface at 03 GMT when the temperature fall was reduced and the visibility increased above the fog limit at 06 GMT. Above the fog the sky was cloudless at the time of clearance though cirrus and altocumulus were reported at 07 GMT. This type of fog formation has been studied by Stewart (1955).

A major factor in clearing this fog during darkness was undoubtedly the mixing downwards of dry air from the top of the inversion by stronger winds which developed at 150-450 m between 23 and 05 GMT. In that period the wind at and between these heights increased from 8-10 Kn to 13-17 Kn whilst the surface wind decreased from 4 Kn to 0-2 Kn. At higher (geostrosphic) levels of 600-900 m the windspeed remained unchanged at 8-10 Kn during this period, and it is doubtful if any synoptic evidence other than the Balthum would have detected the strengthening wind at 150-450 m.

iii) 14-15 November 1976, (Fig 6) - Fog formation after sunset and dispersal before sunrise by the advection of a cloud layer above

A deep moist layer up to 250 m was present at sunset but with calm winds between the surface and 100 m cooling was confirmed to the surface layer and fog formed soon after sunset, with a mainly clear sky. By 18 GMT the fog was sufficiently dense for the inversion base to lift from the surface. It levelled-off at 80 m until 00 GMT when it began to descend slowly and reach the surface about 07 GMT when the fog cleared, just before sunrise. Whilst the inversion base descended the inversion top increased in height; the depth of the inversion layer increased from 140 m at 00 GMT to 250 m by 06 GMT yet the temperature difference from base to top remained unchanged at about 3.5°C. This sort of change can sometimes be associated with the intrusion of a cloud layer above the fog, and indeed when the sky became visible at 06 GMT almost complete cover of stratocumulus was observed at 1500 m. Undoubtedly, reduced radiational cooling from the fog top caused the sharpness of the inversion to be lessened and thereby assisted downward mixing of drier air into the fog top. Wind changes in and near the inversion layer were small.

iv) 14-15 December 1976, (Fig 7) - A persistent deep fog

A deep moist layer extending to 350 m produced a surface fog from about 1430 GMT but no well-defined inversion aloft was noted at 17 GMT, probably because the fog contained insufficient liquid water to cause lifting of the inversion until about 20 GMT. The nocturnal inversion was not well-defined until some time before 23 GMT, but the time resolution of the Balthum soundings was insufficient to define the change very well. The inversion, once formed, strengthened and its base rose to 250 m by 04 GMT at which time the fog temporarily rose from the surface to become stratus at 150 m, shortly after a period of slightly-strengthened surface winds. Thereafter the fog reformed and the base of the inversion descended slowly to reach the surface at the time of sunset, 16 GMT, and the visibility rose to the fog limit one hour later. The decrease in the height of the base, and the top, of the inversion may have been due to wind speeds of 12-15 Kn in the inversion layer noted just before descent began. Also a temporary break in the fog at 07 GMT revealed large amounts of stratocumulus at 1500 m, but this cloud layer had disappeared again when the fog finally cleared. Surface wind speed remained between 2 and 6 Kn during the whole period except for a calm when the fog lifted to low stratus between 04 and 07 GMT. The fog top, deduced from the base of the inversion and the top of the moist layer, which lay close to each other, was probably about 30-40 m above the inversion base.

v) <u>14-15 February 1977. (Fig 8) - Fog lifting to low stratus</u>

Evening mist thickened to fog by 22 GMT with surface wind of 6 Kn at 10 m at the time of formation. A deep moist layer of 200 m stirred by winds of up to 7 Kn did not prevent a marked surface inversion forming. The base of this inversion lifted off the surface to reach 150 m by 05 GMT where it remained until lifted further by rising surface temperatures after 11 GMT. In this fog the top may well have extended to near the top of the inversion as the air was close to saturation up to that level. Above the fog winds were 4-8 Kn increasing to 10-17 Kn by 09 GMT. These stronger winds, and rising surface temperatures, lifted the fog to become stratus cloud.

vi) 16-17 October 1977, (Fig 9) - A typical autumn fog forming after sunset and lifting to become low stratus during the late morning

With only small amounts of cirrus at sunset ground fog patches formed at 17 GMT and remained shallow with the sky visible until 21-22 GMT when the fog thickened. Due to radiational cooling at the fog top the base of the nocturnal inversion lifted from the surface at about 23 GMT and levelled-off at 150 m by 03 GMT. At the time of the shallow fog formation during the evening surface winds were 2-3 Kn at 10 m and 36 m but subsequently increased to 5-6 Kn whilst shallow fog persisted. At the time of thickening and deepening the surface wind dropped to 2 Kn at 10 m and 36 m and remained at that value for the rest of the night. When the fog deepened winds at 150-300 m had doubled their earlier speeds to become 12-13 Kn but decreased again by 05 GMT to become 6-9 Kn. The moist layer became deeper for a time about 08 GMT when intermittent light drizzle was recorded. Thereafter insolation raised the surface temperature at 1°C/hr and the fog lifted to stratus between 11 and 12 GMT.

The analysis of Fig 9 demonstrates the differences which exist between ascent and descent data, where the inversions associated with fog and sampled by descents are much shallower and sharper than those recorded on ascents. The discrepancies shown in Fig 9 are those shown in profile form in Fig 3, but many other examples can be noticed in Figs 4-12.

vii) 17-18 October 1977 (Fig 10) - An autumn fog with advective changes aloft

The top of the moist layer was variable in height but a shallow fog formed under a clear sky between 20 and 21 GMT. The fog remained shallow with the sky visible until 00 GMT when deepening fog obscured the sky as the nocturnal inversion lifted from the surface to level-off at about 200 m. The inset to Fig 10 shows the base of the inversion as deduced from the rather poor time and height resolution of the Balthum soundings and the fog top height as measured by accoustic sounder, point visibility meter (PVM) and droplet spectrometer (ASSP)

Measurements by these devices show short-period fluctuations of the fog top height which could not be detected by the relatively infrequent Balthum soundings. At 2330 and 0330 GMT when measurements of fog top height coincided with Balthum ascents, the fog top was 50-100 m above the inversion base. By 10 GMT, some four hours after sunrise, the fog had lifted to become stratus cloud trapped under a steepening inversion. The stratus subsequently evaporated as surface temperatures rose and only small amounts of cloud remained at 240 m by 12 GMT. The intensification of the inversion was very marked between 03 and 10 GMT with the temperature at 450 m rising by 4°C whilst the inversion base temperature remained unchanged.

Strengthening winds above the inversion base produced an advective change of air, confirmed by marked changes in the wet bulb potential temperature especially at the 450 m level.

viii) 19-20 December 1977, (Fig 11) - A shallow evening fog deepening to produce continuous drizzle

Shallow fog patches formed at sunset with calm surface winds and half-cover of cirrus cloud. The ground-based inversion lifted aloft sometime before 23 GMT when the sky became obscured as the fog deepened. The moist layer also grew upwards as cooling proceeded and reached a pre-existing cool layer near the base of an upper inversion at about 400 m. Drizzle commenced at 05 GMT, the time when the fog top probably reached the 400 m level, and continued until just before sunrise and the lifting of the fog to low stratus at 07-08 GMT. There was no significant change of wind direction or speed at the time the fog lifted, but the surface temperature was rising slowly.

ix) 18 January 1978, (Fig 12) - A supercooled fog forming at dawn and persisting until evening

Patchy fog formed just after dawn with surface wind steady at 4-5 Kn and persisted until 21 GMT. Rime ice was deposited between 12 and 20 GMT. The fog grew upwards to 150 m with measured fog tops about 30-50 m above the inversion base, and there was some evidence of a clearance in the height of the inversion base before the fog cleared. Winds just above the fog layer increased from 4-7 Kn to 8-14 Kn as the fog top began to descend slowly, probably due to the downward mixing of dry air into the fog top. The sky was visible during the last three hours of fog and was cloudless until the first observation after clearance when large amounts of stratocumulus were reported. Surface temperatures changed little during the period, usually remaining at -3 or -4°C.

Discrepances between ascent and descent data are again evident in this case.

c) Height of fog top

The total of 26 cases of fog examined, some of which are illustrated in Figs 4-12, all show that at some height (often 50-150 m) above the nocturnal inversion base the dew point depression becomes $\geqslant$0.5°C which implies that the fog top lies between the inversion base and the level of the drier air.

An additional set of data on fog tops exists for six of the cases examined where vertical profilesof droplet spectrometer and point visibility meter measurements were made through the fogs and the heights of the fog tops deduced, (Brown 1980[a]). Some of the fog tops measured in this way are shown in Figs 4, 10 and 12. A total of 62 individual measurements of fog tops from the six cases could be related to the height of the inversion base as deduced from Balthum data obtained within one hour of each fog top observation. These are plotted in Fig 13 and show that all measured fog tops lie above the inversion base. The line of best fit indicates that most fog tops lay about 50 m above the surface-based inversion for the shallowest fogs and about 65 m above the inversion base for the deeper fogs. Standard deviations were about 28 m. This result is broadly consistent with the indications of the time cross-sections.

For one of the fogs detailed temperature soundings additional to those of the Balthum were made by a device attached to the same balloon as the droplet spectrometer and the point visibility meter. These temperature soundings gave much more detailed resolution than the Balthum system and allowed the base of the inversion to be located very accurately. These measurements were available only for the night of 17-18 October 1977 (Brown, 1980b) and are indicated in Fig 13 by crosses. In this one case all fog tops lie about 15 m above the inversion base of the moderately shallow fog and 15-75 m above for the deeper fog later in the night.

Fog tops are not always, perhaps not usually, sharply defined and the steepness of the inversion may be related to the sharpness or otherwise of the fog top. Brown defined the fog top as the level at which the point visibility meter he was using indicated the visibility to rise above 500 m. Owing to the large gradient of visibility usually found at the fog top the 1000 m visibility level will generally lie close to the 500 m visibility level. However, this is a matter which may need further clarification.

Finally the report by Caughey et al (1978) that the base of the acoustic sounder echo averaged the same height as the fog top measured by the droplet spectrometer appears slightly inconsistent. This was based on only one case study in which the criterion for the droplet spectrometer fog top was not defined.

3. Some characteristics of radiation fog

The nine occasions of fog shown in Figs 4-12 and the other 17 cases not illustrated were all formed by radiational cooling at the surface. Indeed the pre-requisites of clear sky at dusk, moist surface air, light winds and little advective change were necessary for the operation of the enhanced Balthum programme.

The main characteristics of radiation fog are well known from earlier studies, especially those of Roach et al (1976) and Brown et al (1976) who drew attention to short period changes of wind at 2 m in relation to periods of significant fog development, and to the lifting of the nocturnal inversion from the surface as the fog developed, with a lapse rate being established within the fog itself. This present study did not examine the behaviour of wind at 2 m over short time intervals, only the 10 m winds at the hour before - and the hour after - fog formation. It does, however, illustrate the lifting of the inversion base from the surface as the fog developed and the pronounced changes of near-surface lapse rates which followed. The main features which emerge from this study may be summarized as follows:

a) Formation

Fog did not form on the one radiation night when drier air was present at 35-75 m above the surface.

When moist air was present fog generally formed in shallow layers or patches as temperature fell below the fog point, with 10 m winds averaging 4.3 Kn (SD 2.3 Kn) at the hourly observation before fog and averaging 3.4 Kn (SD 2.1 Kn) at the hourly observation after fog formation. Surface temperature continued to fall after formation and the sky generally remained visible.

A few hours after fog formation (Mean 3.0 hr, SD 1.7 hr) the sky became obscured, often without change of horizontal visibility, and the nocturnal inversion lifted from the surface as the fog top became the main radiating surface. A lapse rate became established as the upward flux of heat through the soil became effective in raising the surface temperature or in some cases retarding the earlier fall.

Thus in confirmation of the earlier work of Roach et al (1976), two separate stages of fog formation could usually be identified:-

i) Shallow fog/ground based inversion/sky visible/surface temperature falling.

ii) Deepening fog/inversion base rising/sky obscured/surface temperature fall reduced or reversed.

In 25 of the 26 cases examined here the first stage was followed by the second. The exception to this process occured during the evening of 10 November 1976 when a moist layer extending to 150 m (Fig 5) may have been stirred by winds of 4-10 Kn between 2 and 150 m and cooling spread throughout the layer. However the data available near the time of formation of this fog are inadequate to describe the process, though there is no evidence of initial shallow formation.

b) Persistence

The inversion base generally rose at about 40 m/hr and levelled off at a maximum height of 70-230 m about 2-5 hours after lifting from the surface. The height reached by the inversion base was influenced by the depth of the moist layer. Using only the base and top of the inversion layer and the depth of the moist layer it could be deduced that the fog top often lay about 40 m above the inversion base.

Data from droplet spectrometer profiles in a limited number of fogs indicated that the top of shallow fogs lay about 50 m above the surface-based inversion, and at about 65 m above the inversion bases at 200 m for the deeper fogs.

Because of the time and height resolution limitations of the Balthum data, and the discrepancies between ascents and descents, there is no real evidence in Figs 4-12 of significant short period fluctuations in the height and temperature of the inversion base. In general the inversion base evolves slowly and soundings at about 3-hourly intervals are probably sufficient to yield an overall picture of its development. However, the droplet spectrometer data do show a change of fog top of about 80 m in $\frac{3}{4}$ hour (Fig 4), an event not resolved by the Balthum soundings though a temporary deepening of the moist layer over a $2\frac{1}{2}$ hr period was indicated.

c) Clearance

In the examples shown here clearance of fog takes place in one of three main ways:-

i) A rise of surface temperature due to insolation, leading to thinning and dispersal, or lifting to low stratus followed by dispersal or transformation to cumulus, (Fig 4). In the event of the inversion base rising to meet the top of the inversion, whilst near saturation, fog or low stratus transforms to cumulus. The rate of lifting of the inversion base by insolation is governed by the steepness of the inversion.

ii) An increasing wind speed above the fog leads to a gradual lowering of the fog top, even during the night as drier air is mixed into the fog top. The inversion base may gradually lower to the surface and temperatures there may fall slowly as the radiating fog top approaches. Fig 5 shows an example of this process where the clearance of fog before sunrise was heralded by the sky becoming visible one hour earlier.

iii) A cloud sheet advecting across above a fog may cause its clearance as the net radiation from the fog top is reduced, (Fig 6). The inversion becomes less steep and mixing of drier air into the fog top is assisted, thus lowering the fog top towards the surface. The flux of heat from the soil may also clear the fog at the surface and lift it to low stratus which subsequently evaporates.

Fog may, of course, clear in other ways not illustrated in the examples here; for example by the effect of a strengthening pressure gradient and increasing surface winds. Often this is associated with the process of (ii).

4. Conclusions

The time cross-section of Figs 4-12 show well the time and height changes of structure during fog formation and dispersal, emphasizing the value of high-resolution low-level soundings of temperature, moisture content and wind in studies of fog and other boundary layer phenomena. As an aid to monitoring and prediction of development such soundings at intervals of about 3 hours would be invaluable to a forecaster, though they would not reveal the short period fluctuations cited earler.

For example, a forecaster needs to know:-

For radiation fog formation

a) Upper temperature and dew point profiles for calculation of fog point.

b) Depth of the moist layer.

For fog persistence

a) The height of the base of the inversion, to deduce fog depth.

b) Systematic changes in height of the inversion base and top, and changes of temperature. Trend of the changes.

c) Upper winds above the fog layer.

For fog clearance by insolation

a) The height of the base of the inversion, to deduce fog depth and hence time of likely clearance (e.g. Heffer, 1965)

b) The steepness and magnitude of the inversion to deduce mode of clearance, e.g.

i) Evaporation of fog

ii) Lifting to low stratus followed by complete clearance of cloud.

iii) Lifting to low stratus, followed by transformation to cumulus.

Classes ii) and iii) introduce a risk of fog after dawn at higher-level stations which may have remained fog-free during the night.

The development and use of mini-sondes, accustic sounders, mast data and other systems giving detailed information of the kind shown here in the boundary layer would be invaluable to forecasters and researchers, especially in areas remote from stations making routine upper air soundings.

Met 09

10 March 1981

References

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Brown R		I - a field study
Caughey SJ		Quarterly Journal of the Royal Meteorological Society,
Garland JA		Vol 102, pp 313-333
Readings CJ		
Stewart KH	1955	Radiation fog: Investigations at Cardington 1954-54.
		Air Ministry. Met Research Paper No. 912.

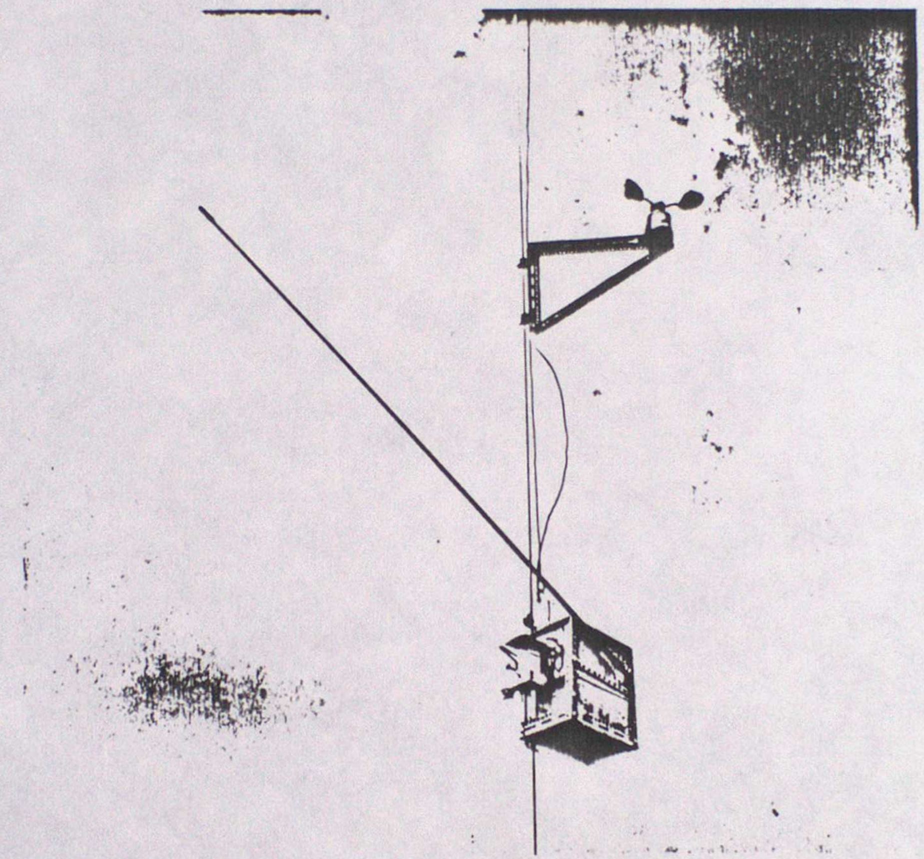
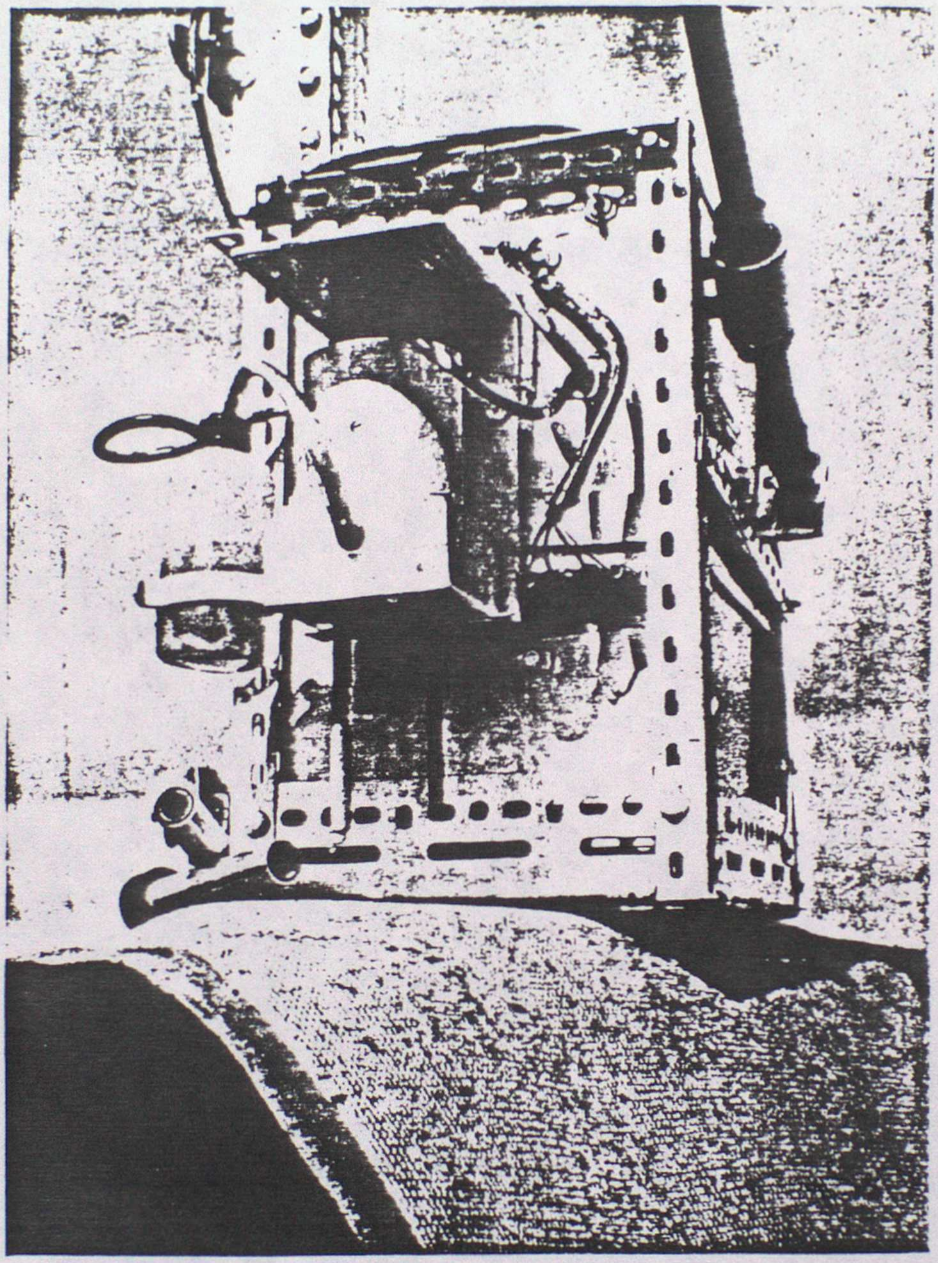


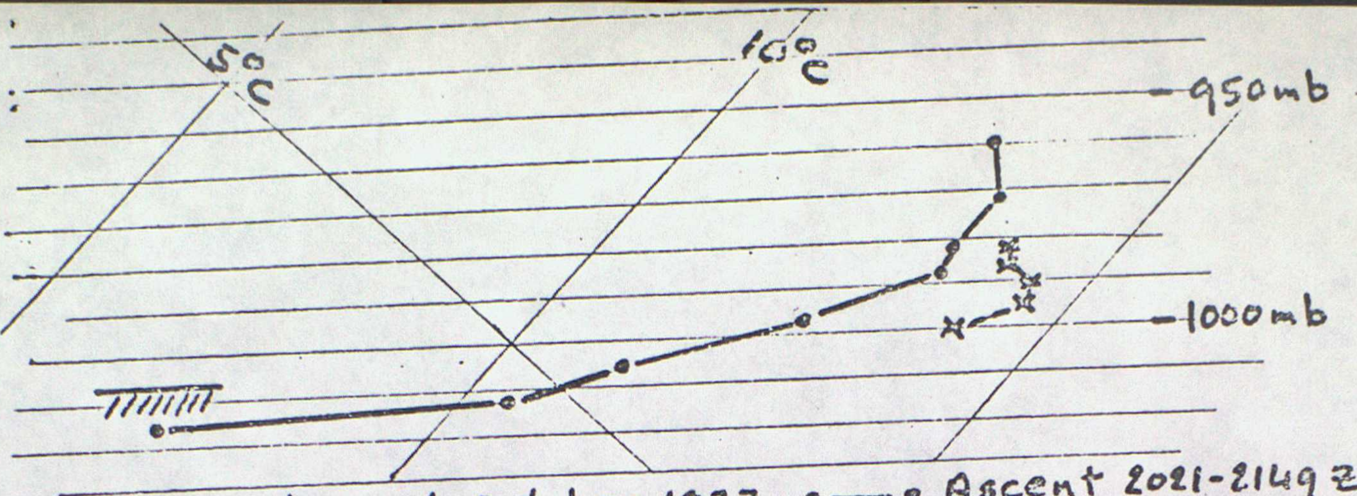
Fig.1 The Balthum instrument package.



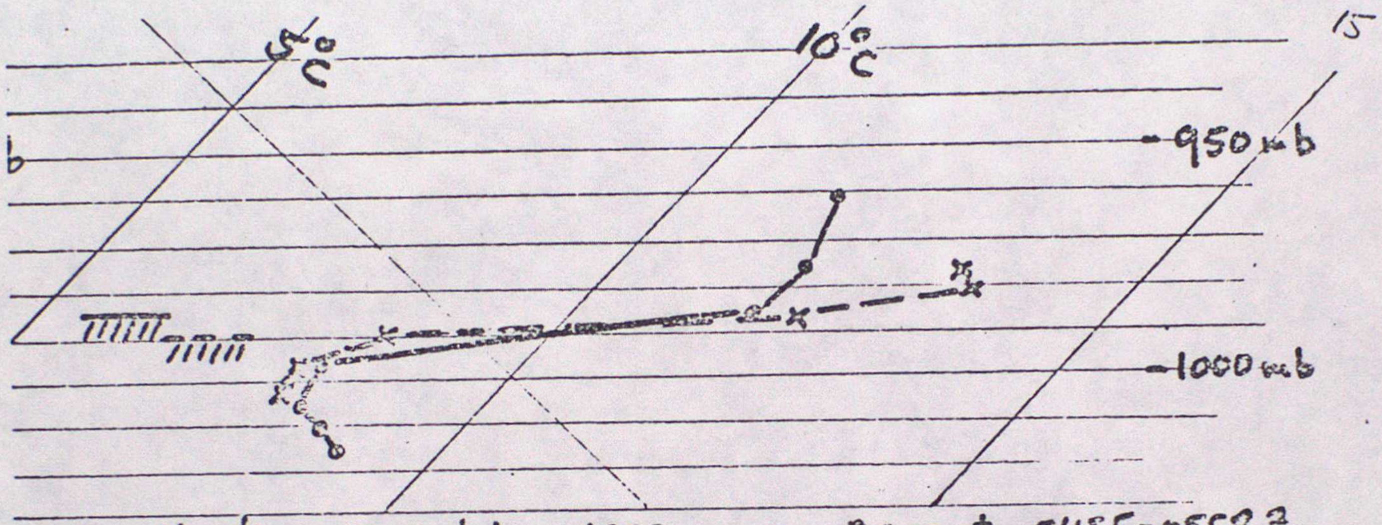
~~PLATE I TETHERED RADIOSONDE SHOWING PSYCHROMETER WITH SHIELDS REMOVED FROM TEMPERATURE SENSORS~~

See page 95

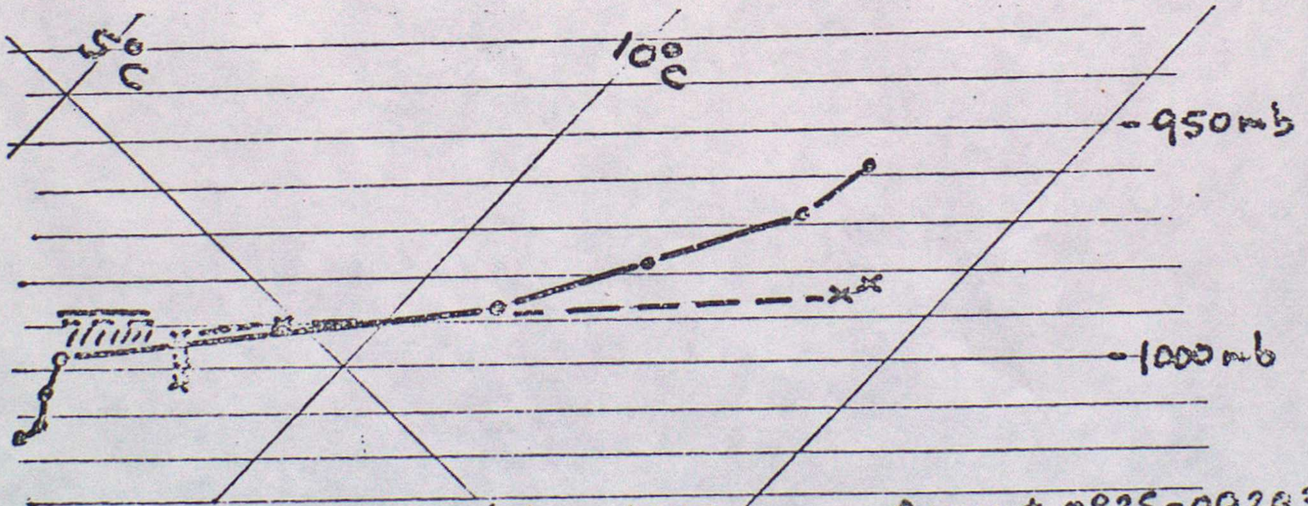
Fig 2. Details of the Balthum instrument package



Cardington 16 October 1977 •——• Ascent 2021-2149 Z
x - - x Descent 2200-2244 Z



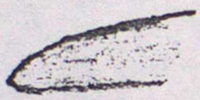
Cardington 17 October 1977 •——• Ascent 0455-0558 Z
x - - x Descent 0620-0650 Z



Cardington 17 October 1977 •——• Ascent 0825-0929 Z
x - - x Descent 0937-1025 Z

Fig. 3. Balthum soundings made during the fog of 16-17 October 1977.
Fog tops are indicated symbolically at the left hand side of each sounding.

Legend to Figures 4 – 12

——— 5	Isotherms, deg C
- - - -	Inversion base
....	Inversion top
/ \	Balthum ascent, descent
s↑R	Sunrise
s↑s	Sunset
	Moist air Dew point depression ≤ 0.5° C
	Cloud base
V V	Visibility, m.
ff_{36}	Wind speed at 36 m, kn.
ff_{10}	Wind speed at 10 m, kn.
ff_{2}	Wind speed at 2 m, kn.
⑥	Wind speed aloft, kn.
+++++	Fog top, from droplet spectrometer

CARDINGTON · 27 October 1976

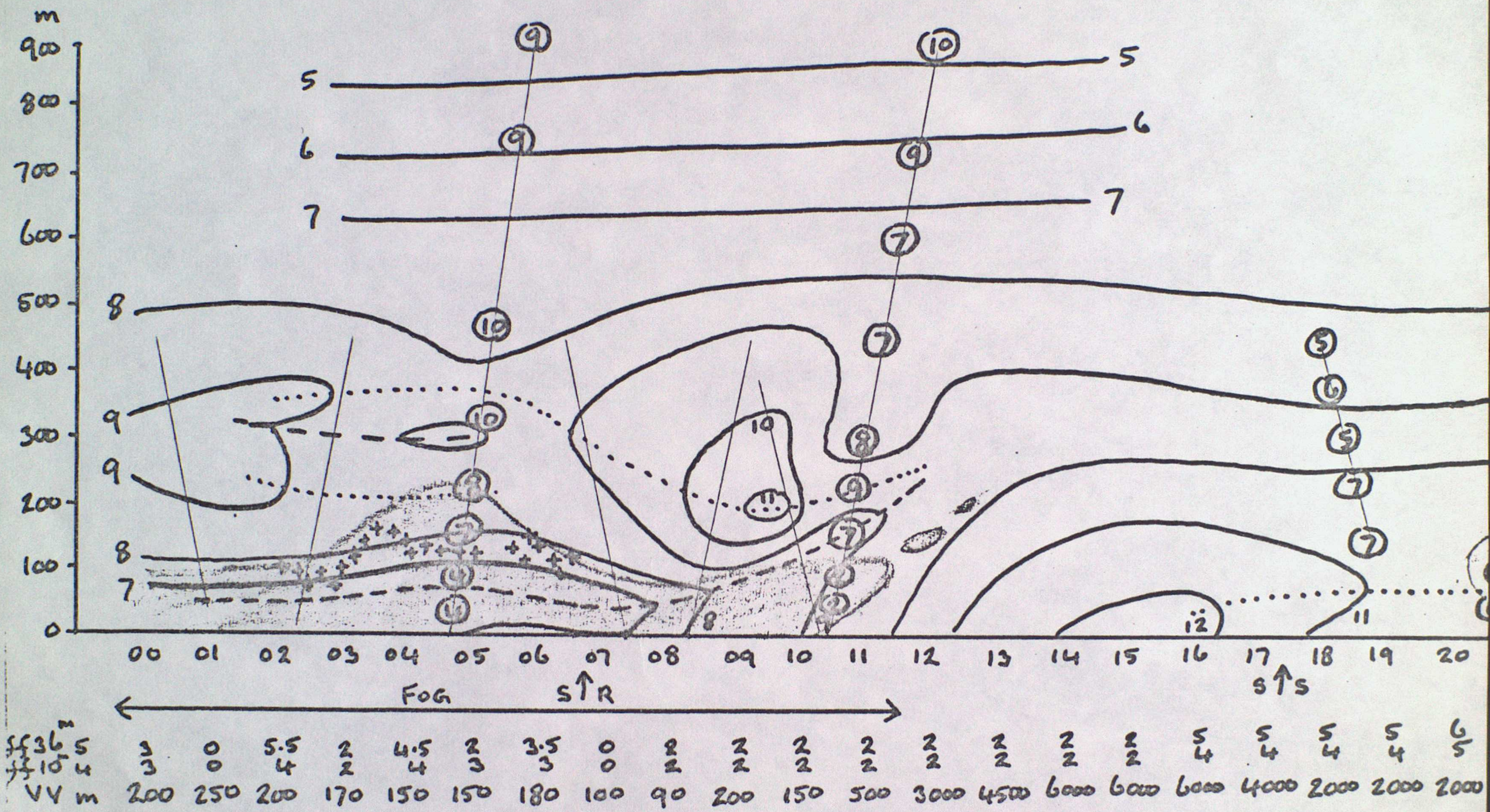
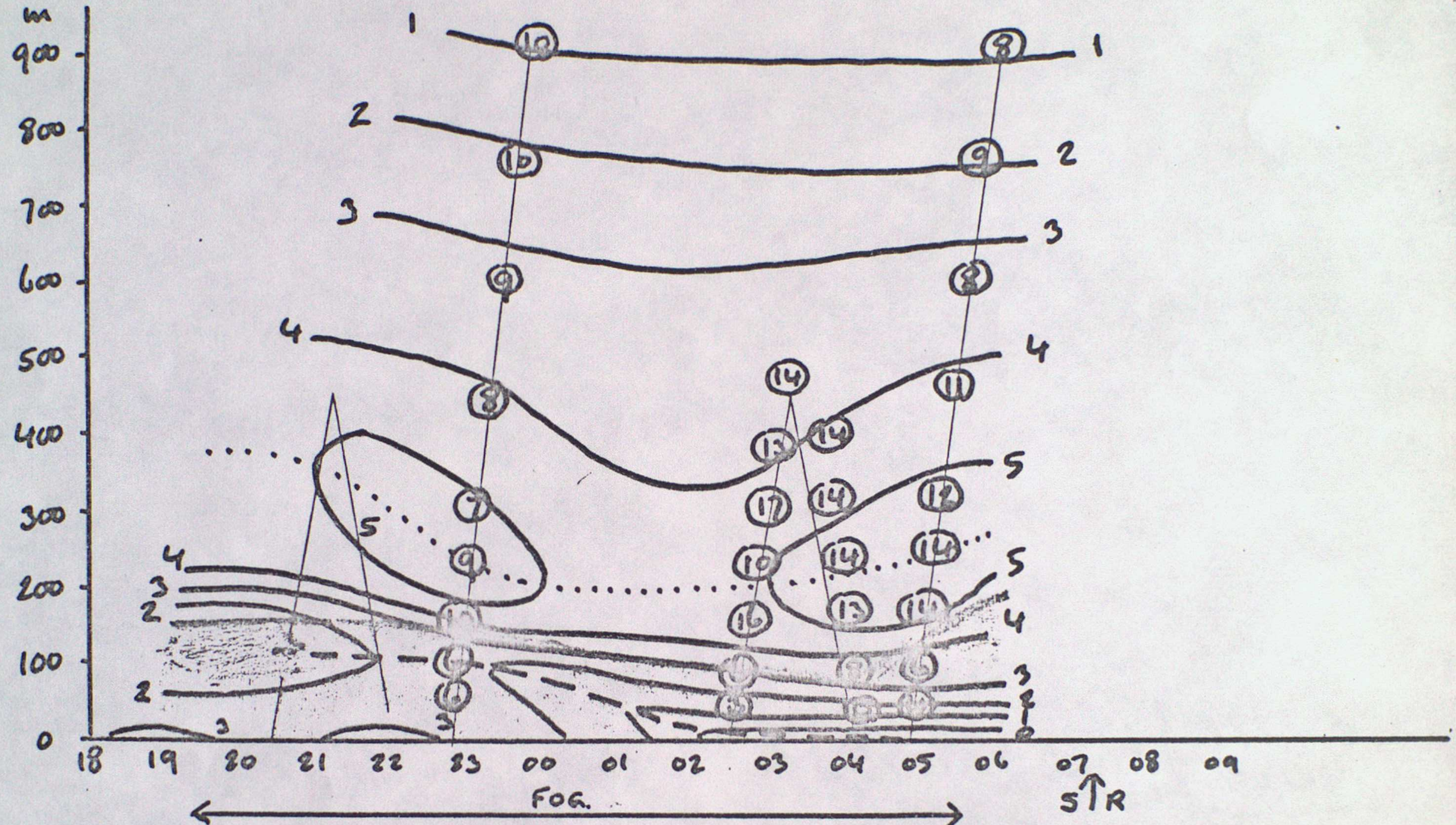


Fig. 4.

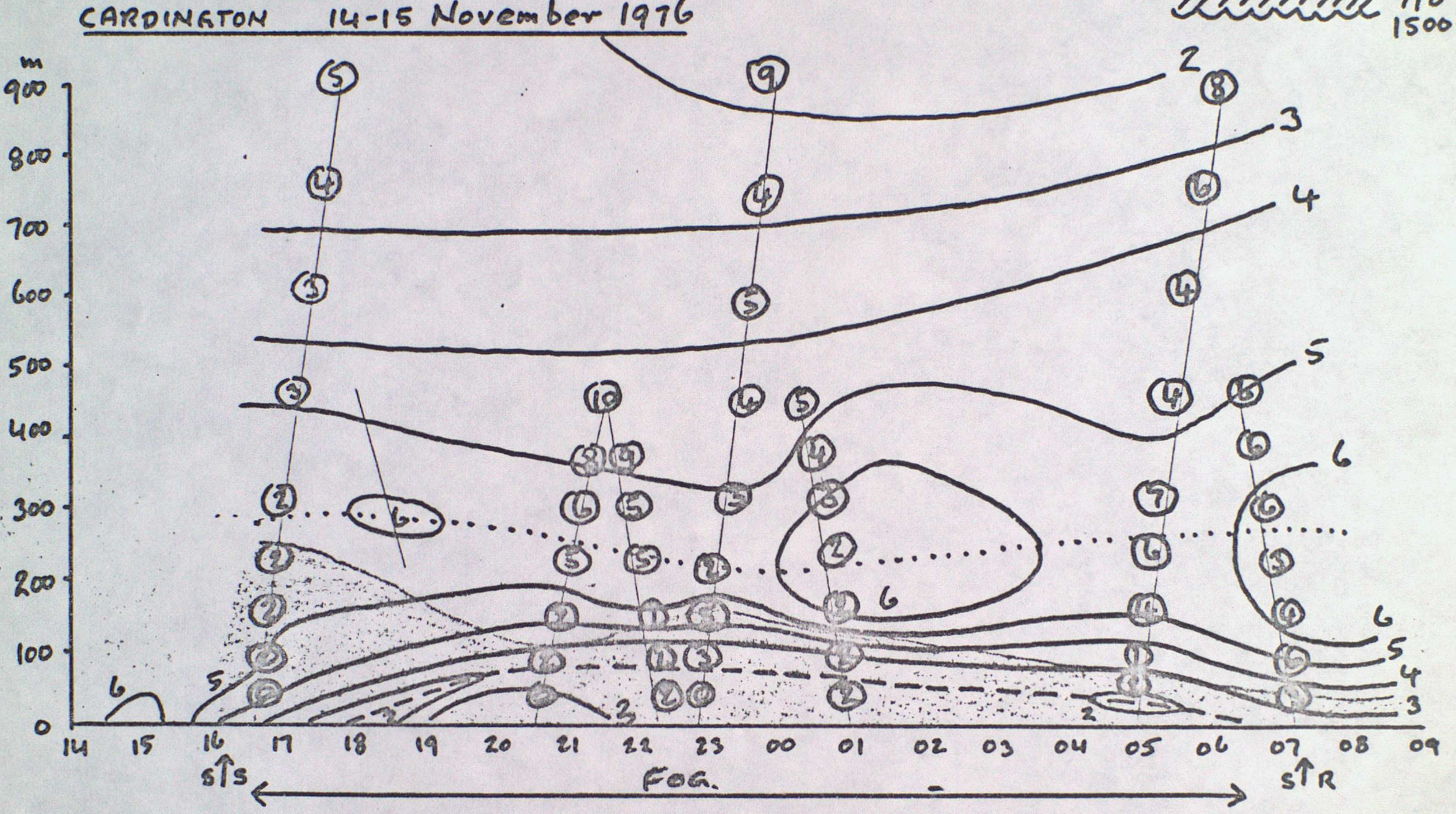
CARDINGTON 10-11 November 1976



	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09
ff36	8	7	6	6	5.5	4	3	0	4	0	2	4	3	2	2
ff10	6	6	5	5	4	3	2	0	3	0	2	3	2	2	2
ff2	4	4	4.5	3.5	3.5	2	1	1	1	0.5	0	1	1	1	1.5
VVm	2000	400	200	180	100	80	90	90	120	100	850	1200	3000	2000	2000

Fig.5

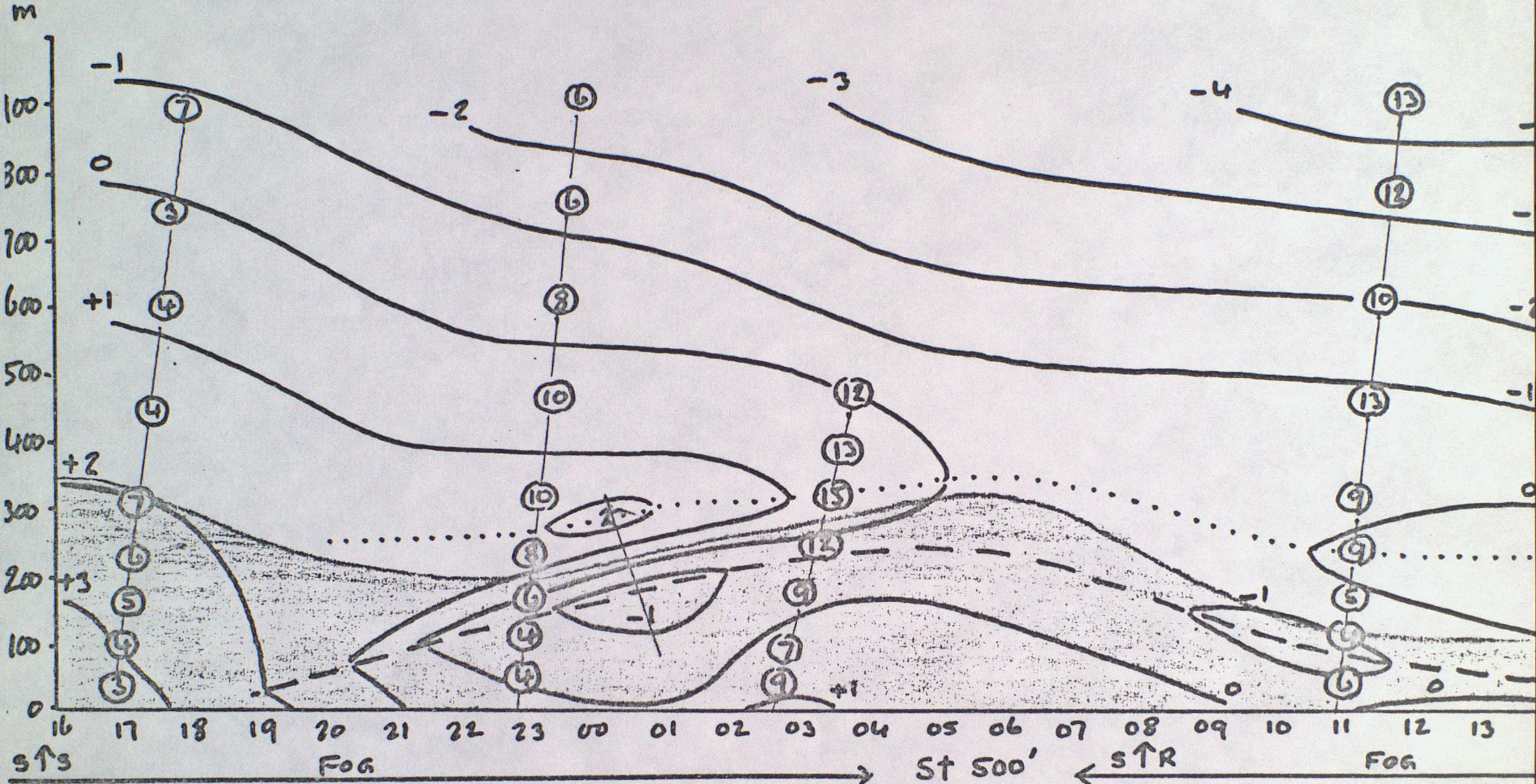
CARDINGTON 14-15 November 1976



ff 36m	0	2	0	0	0	6	2	2	2	0	2	2	0	0	2	2	4	2	2
ff 10m	0	2	0	0	0	5	2	2	2	0	2	2	0	0	2	2	3	2	2
V' n	2000	2000	2000	80	50	70	70	90	80	100	80	500	1200	700	120	80	500	1100	2300

Fig. 6

CARDINGTON 14-15 DECEMBER 1976



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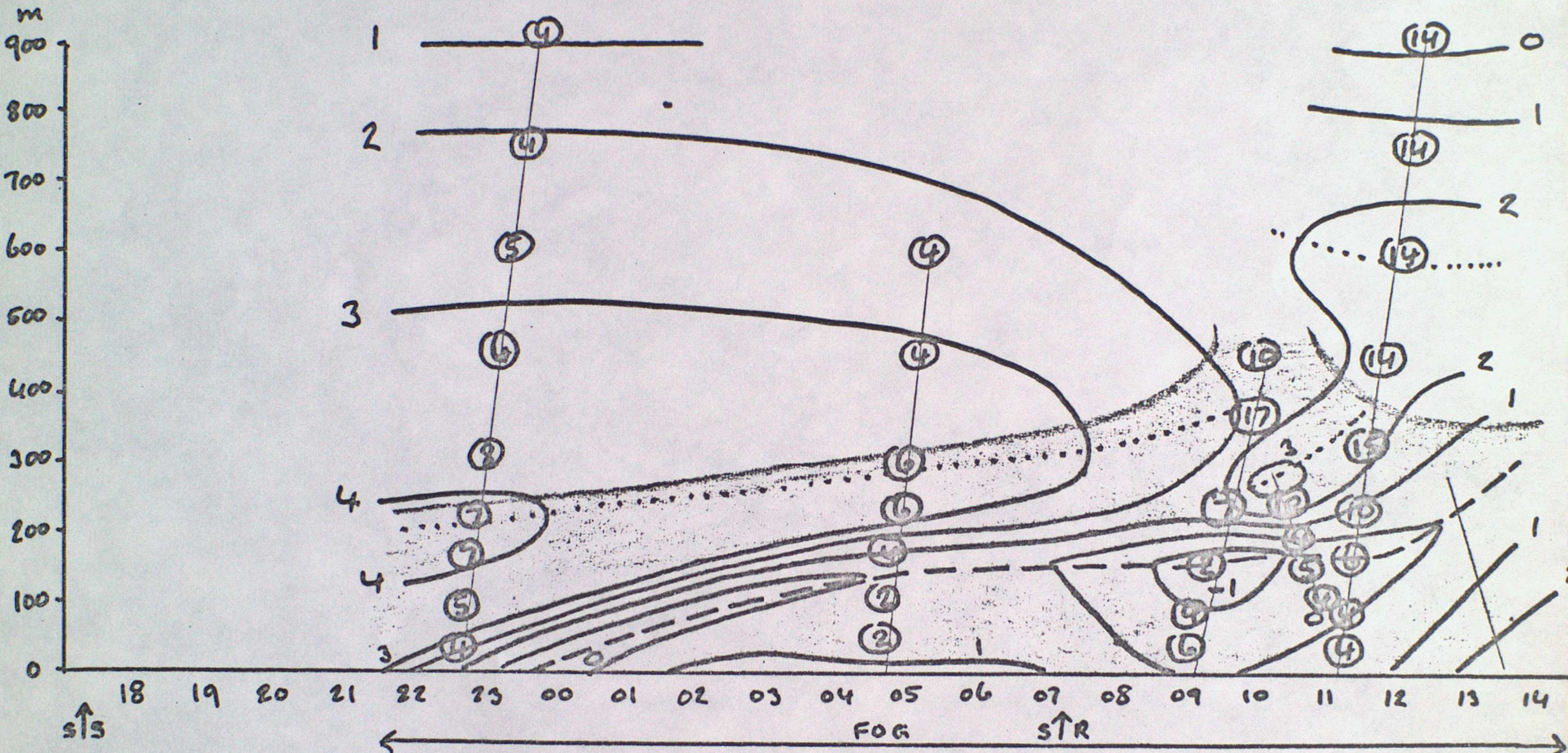
	16	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09	10	11	12	13
f36	3	4	7	7.5	5	2	5	4	4	5	7	6	3	0	0	0	3	4	2	5	2	2
f10	2	3	6	4	4	2	4	3	3	4	6	5	2	0	0	0	2	3	2	4	2	2
N	500	900	900	400	150	200	200	150	200	250	300	500	900	2500	1800	1200	150	120	100	200	400	700

Fig. 7

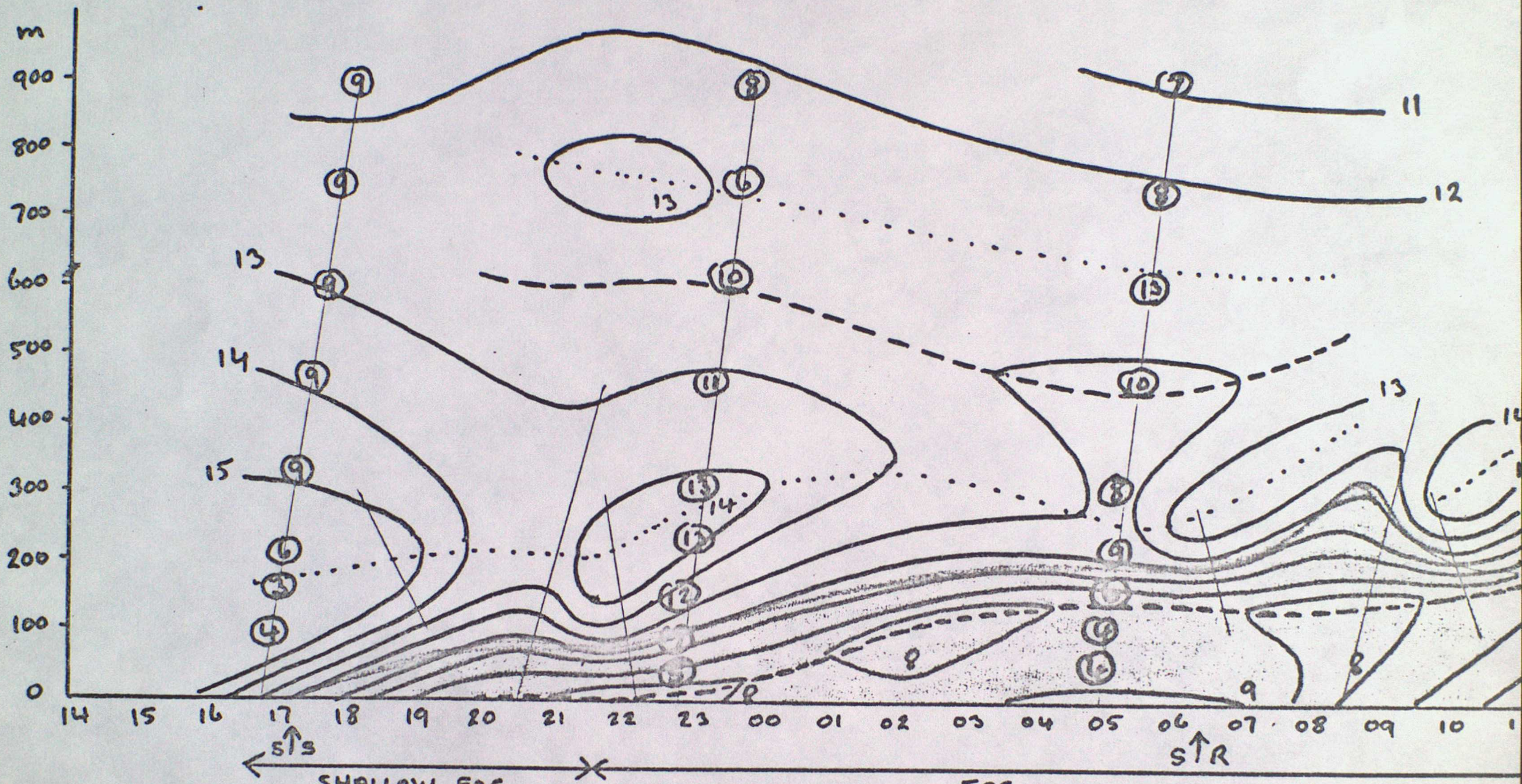
CARDINGTON 14-15 February 1977



	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
ff36			9	9	7	8	0	2	2	0	0	0	0	0	2	2	2	5	5	6	7
ff10			7	7	6	4	0	2	2	0	0	0	0	0	2	2	2	4	4	5	6
VVm			6000	3500	80	80	70	70	50	50	60	80	70	80	150	150	150	170	200	350	1000

Fig. 8.

CARDINGTON 16-17 October 1977



	14	15	16	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09	10	11
																			9			
ff36	3	3	4	3	4	5	6	6	2	1	2	3	2	2	2	2	4	5	3	4	5	5
ff10	2	2	3	2	3	4	5	5	2	2	2	2	2	2	2	2	3	4	2	3	4	4
VV m	2500	3000	3800	2800	700	150	800	40	40	40	50	60	60	80	80	80	90	90	120	150	200	50

Fig. 9.

CARDINGTON 17-18 October 1977

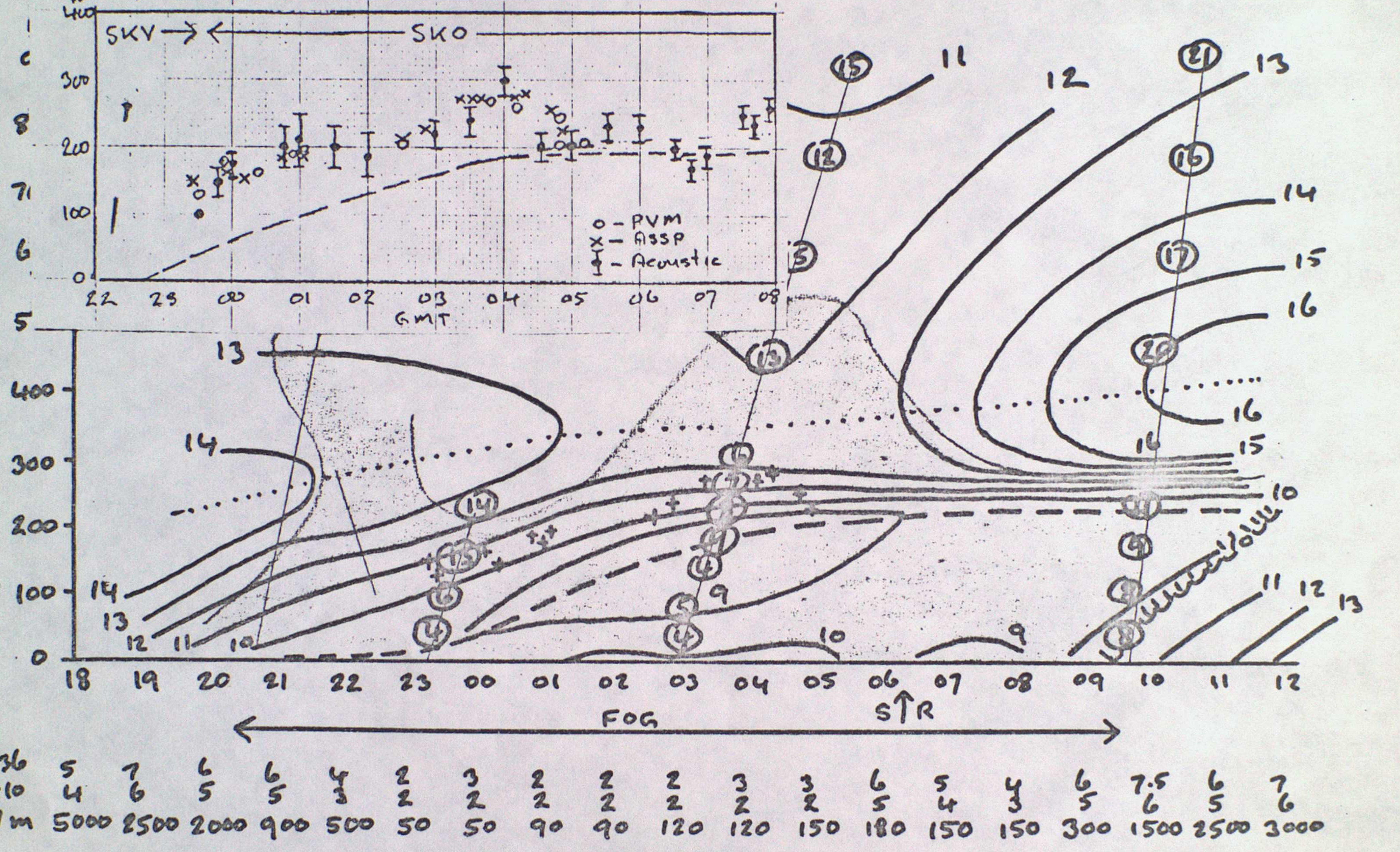
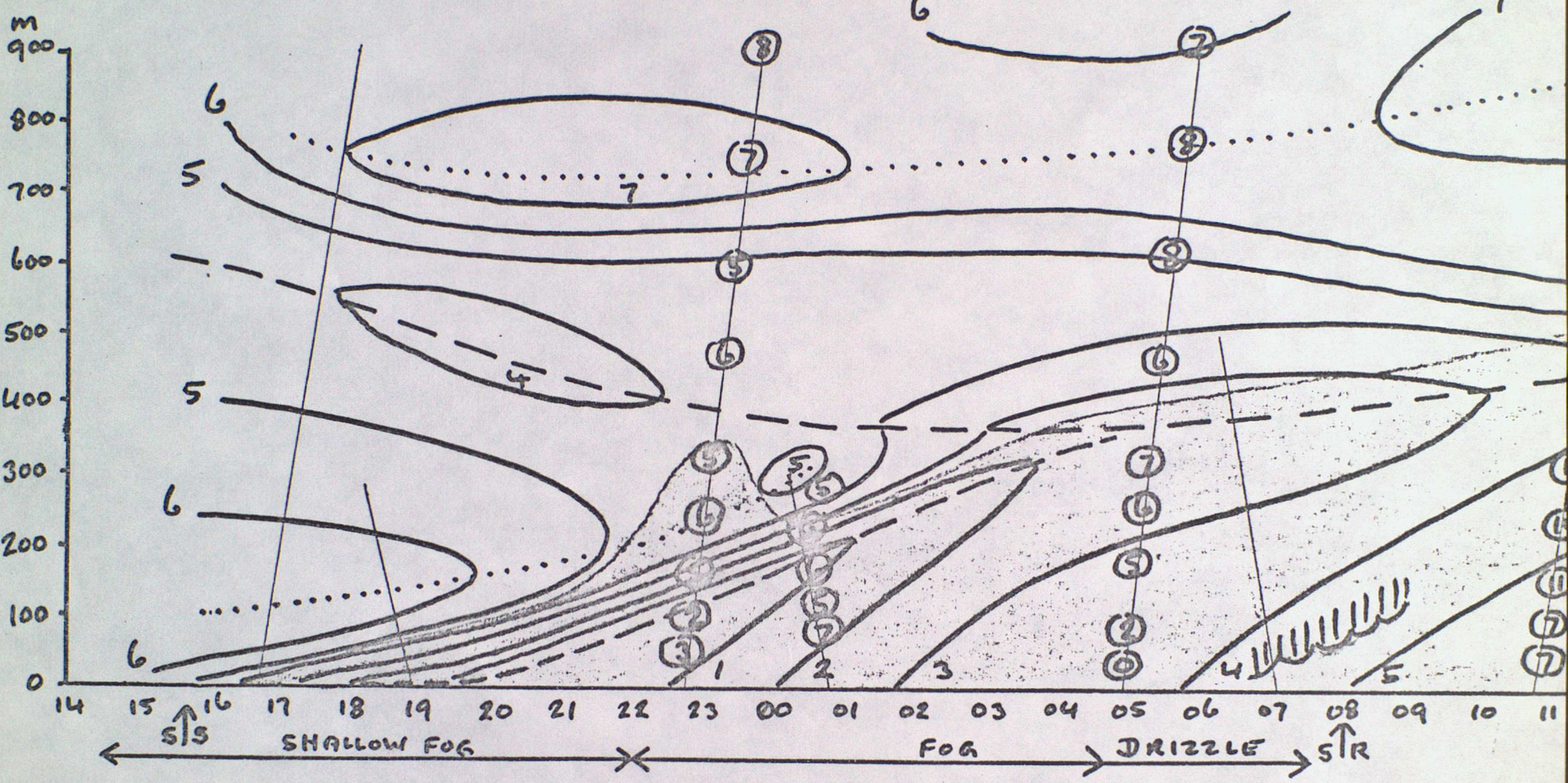


Fig. 10.

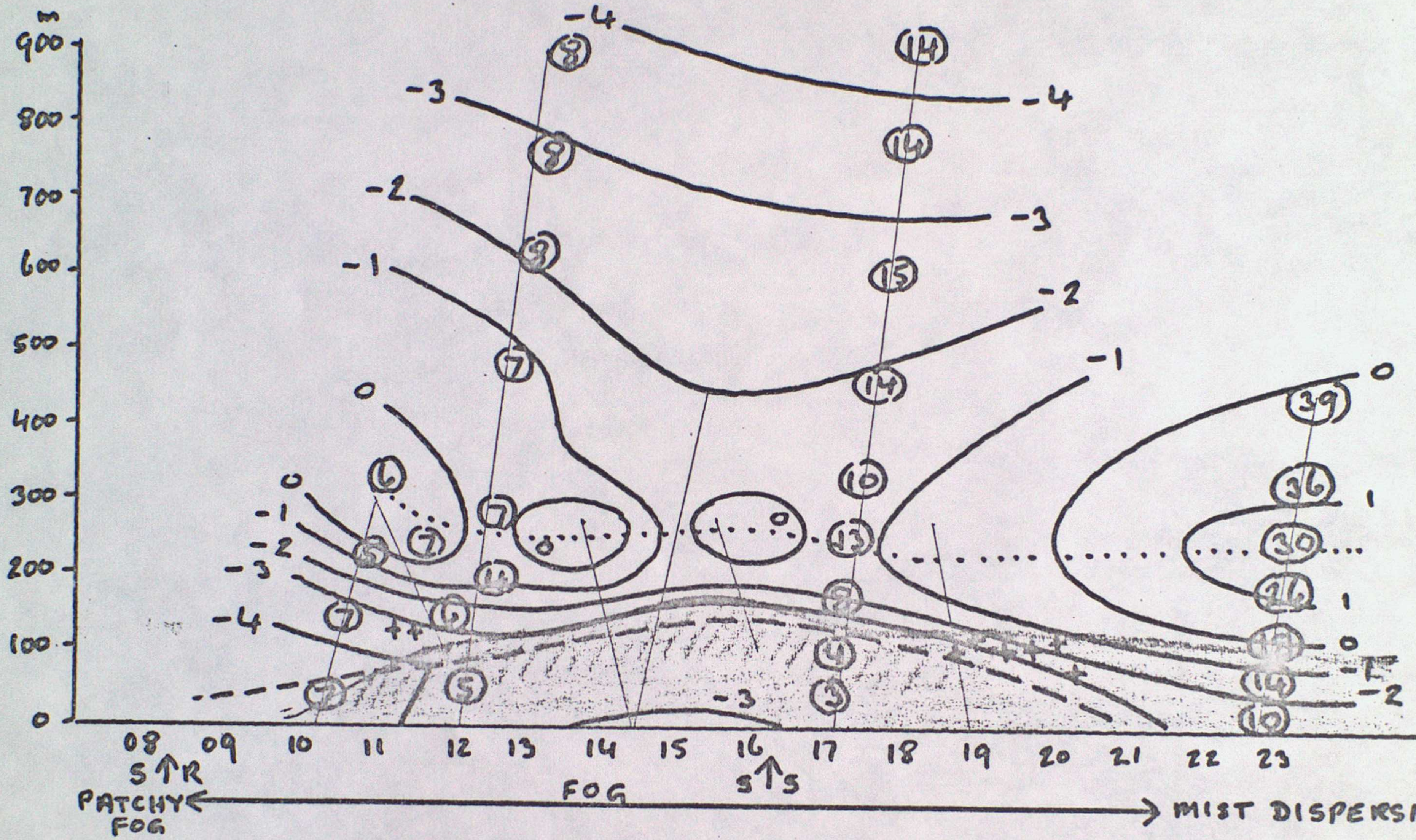
CARDINGTON 19-20 December 1977



	14	15	16	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08
ff36	2	0	0	0	5.5	3	0	2	2	2	2	4	3	4	3	2	4	5	4
ff10	2	0	0	0	4	2	0	2	2	2	2	3	2	3	2	2	3	4	3
VVm	2500	3000	90	180	350	150	50	80	90	70	50	50	90	150	200	100	100	500	1500

Fig. 11

CARDINGTON 18 JANUARY 1978



ff36	5	5	6	5	5	3	5	3	3	3	2	2.5	3	5	11
ff10	4	4	5	4	4	2	4	2	2	2	2	2	2	4	9
VVm	2500	180	150	100	60	40	40	80	90	90	150	250	250	600	5000

Fig. 12.

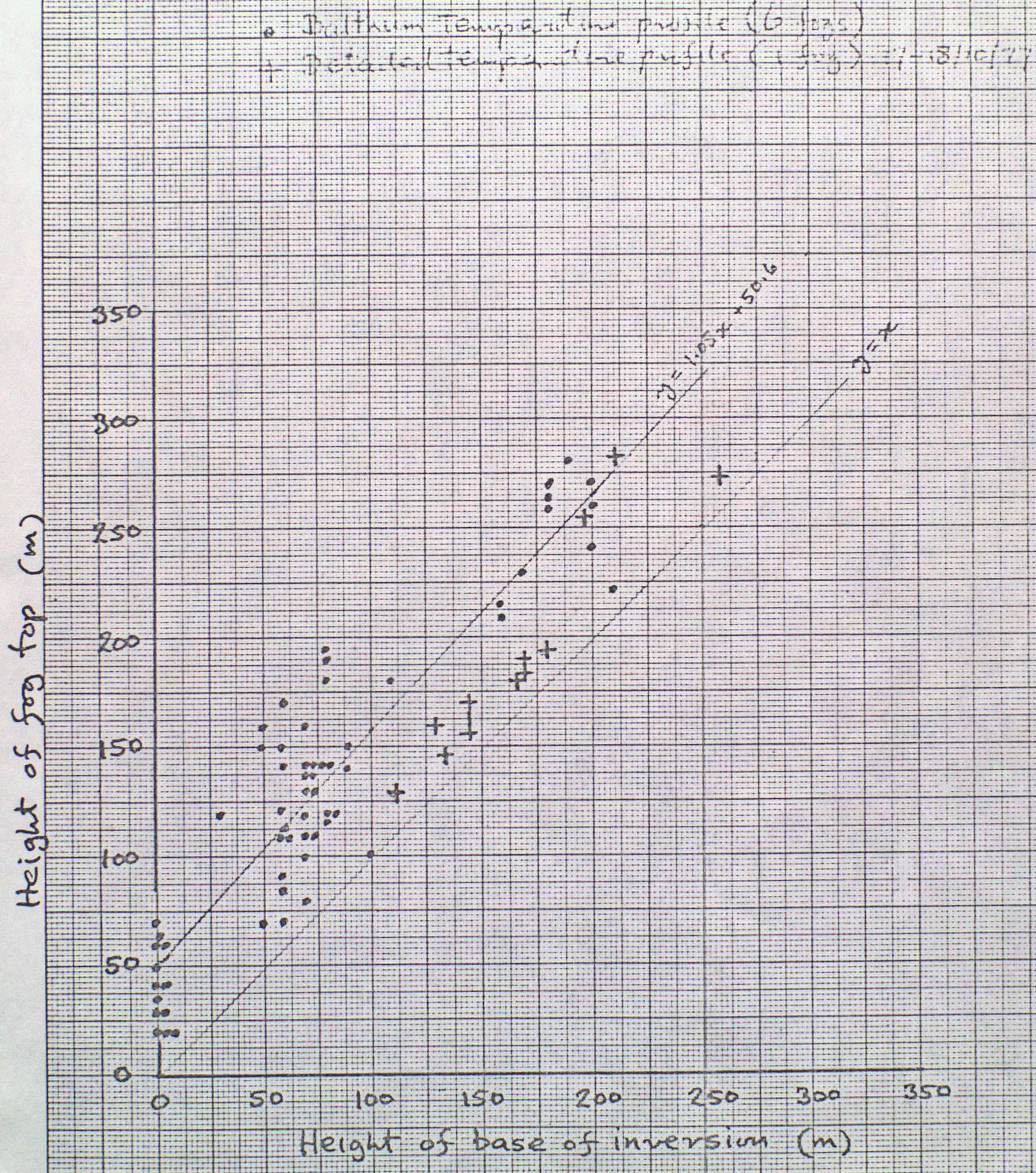


Fig. 13 Height of fog top as measured by droplet spectrometer related to height of base of nocturnal inversion deduced from Balthum soundings.