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"An investigation of Nimbus 5 SCR data and the quality of stratosphere thicknesses deduced by single and multi-channel regression techniques during the 1974/75 mid winter warming".

by

N R Watson

Met O 19
High Atmosphere Branch
Meteorological Office
London Road
BRACKNELL
Berkshire RG12 2SZ

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1. Introduction

Slingo (1976a) has compared radiances measured by the Selective Chopper Radiometer (SCR) on Nimbus 5 with the simulated radiances computed from the weighting functions and colocated radio/rocket sonde temperature profiles at West Geirinish and Wallops Island. His study used observations for July and August 1974 and February 1975.

The present paper describes another comparison made using rocket sonde observations covering the Northern Hemisphere during the period of a mid-winter stratospheric warming, December 1974 and January 1975. In this case colocations were not attempted. Satellite radiances have been interpolated from daily charts for comparison with simulated radiances computed in a similar way to Slingo. Further, from these comparisons, regression equations were developed involving a given stratospheric thickness and the radiances in the four channels of the SCR. This work was done in the course of preparing high stratospheric charts during the period of the warming using mainly satellite data. The large scale features of the stratospheric circulation will be presented in another paper (Watson (1977)) which is a sequel to a study on the lower stratospheric circulation during the same period (Watson (1976)).

2. Method of Analysis

Radiance data for the B12, B23, B34 and A1 channels of the SCR on the Nimbus 5 satellite were supplied for the two months of December 1974 and January 1975 by the Department of Atmospheric Physics, Clarendon Laboratory, Oxford. Radiance values are provided for locations defined by a grid with intervals of 4° in latitude, from the Equator to 80°N, by 10° in longitude. The grid point values are means over a 24 hour period and were assumed to be appropriate to 12Z on the day. Simple linear interpolation was used to estimate the 4 radiance values at the time and position of each rocket launch. On some days there were areas with missing data. If such an area occurred over a rocket station on the day of a launch, then that ROCOB could not be used in the analysis.

However some ROCOBS were recovered by drawing smooth isopleths of radiance across the areas of missing data and estimating the values at the rocket station. This was only done when it was possible to draw good radiance charts on the days before and after the missing data day. An estimate of the radiance at the rocket station could then be made and the linear interpolation applied.

Wherever possible, a temperature profile was constructed from the surface to 0.15 mb, using the rocket sonde temperatures and the nearest radiosonde's temperatures (Campbell (1976)). The nearest radiosonde station was usually within 50 km of the rocket station and only those observations within 12 hours of the rocket launch time were used.

The full temperature profile could not always be obtained because either the radiosonde failed to reach 50 mb or there existed an arbitrarily chosen temperature difference ($> 5^{\circ}C$) between rocket and radiosonde at 50, 30 or 20 mb. Out of 120 rocket launches during the two months, 97 complete temperature profiles were obtained.

For each of the profiles, the simulated (ie calculated) radiance in each channel was computed using the theoretical weighting functions for the SCR provided by Oxford University (although at that time, evidence had been accumulating for the experimenters to consider that the weighting functions were moving upwards). When the temperature profile did not reach 0.15 mb but reached at least 0.3 mb, it was assumed that isothermal conditions existed above 0.3 mb. The simulated radiance would therefore be too high if the true temperature decreased with height above 0.3 mb. This induced error would have an effect only on the B12 channel which has an appreciable weighting function at these levels (13.6% of its weighting function above 0.3 mb as compared with 2.9% in the case of the B23 channel).

Table 1 shows the simulated and measured (interpolated) radiances for each rocket sonde launch, sorted by station. Table 2 is a summary of table 1; it shows the mean measured minus simulated radiance (SAT-ROC) for each station and the overall means and standard deviations for all comparisons and for just those involving the US Data Sonde.

3. Discussion

The points to note from Tables 1 & 2 are the overall mean errors in the B12 and B34 channels. The radiances measured by the satellite are lower than the simulated radiances for the B12 channel while they are higher for the B34 channel. The present results can be combined with other published analyses to show how the apparent radiance errors have changed during the period 1973-77. Figure 1 shows SAT-ROC differences for the B12 and B34 channels. Only results obtained by comparing the SCR with the US Data Sonde (the most widely used rocket sonde) have been used. However the comparisons with the UK Skua sonde given in Table 2 and reported by Slingo (1976a) have been included because of our particular interest. The drift in the B12 channel is so rapid that frequent standardisation against rocket sondes would be necessary before the data could be used for stratospheric analysis. However the drift could be neglected over the 2 month period of this study.

The differences may have been caused by errors in the basic radiometry of the SCR or in the weighting functions, which may have drifted since launch. Temperature errors in the rocket sondes, which would depend on sonde type, could also be a cause.

All these errors would be partially obscured by the random errors in the SCR, in the rocket sonde temperature profiles and in the spatial and temporal interpolations which were discussed in the previous section.

If the weighting functions have drifted with time, it may be possible for this effect to be seen in the bias errors found in the channels for different temperature profiles. Figures 2(a)(b) and (c) were drawn for the temperature profiles that gave the maximum and minimum SAT-ROC difference for the B12, B23 and B34 channels respectively. The arrow on each profile indicates the level of the peak of the weighting function. The first of the two numbers with each profile gives the observed value of radiance measured by the SCR and the second gives the simulated radiance computed from the profile and the weighting function.

In figure 2a the simulated radiances are 10 RU higher than the observed for the profile with a strong temperature lapse rate, whereas for a pseudo-isothermal profile, the observed radiance is greater than the simulated. Part of this difference for the Barking Sands profile can be explained by the error in the simulated radiance because the temperature profile only reached 0.3 mb. Assuming that the temperature did decrease with height above 0.3 mb and the average temperature from 0.3 to 0.05 mb was 25°C lower than that at 0.3 mb then the simulated radiance error is of the order of 3 to 4 RU. The SAT-ROC differences can both be reduced if it is assumed that the weighting function peak is actually higher than originally thought. Because the stratopause at Barking Sands is level with the original weighting function peak, then any upward (or downward) movement of the peak will reduce the simulated radiances. Also, because Fort Churchill's stratopause is much higher than the WF's peak, a rise in that peak will <u>increase</u> the simulated radiance.

A similar argument to reduce the large differences can be applied to the B34 channel (Fig 2c) and to the Wallops Island profile in figure 2b.

Figure 3 shows the mean temperature profiles found during the 2 months for the "tropical" rocket stations (Kwajalein, Barking Sands, Fort Sherman, White Sands, Point Mugu, Wallops Island) and for the 'Polar' stations (the remainder). It can be seen that the tropical stratopause is a little lower than the polar one and is near to the peak of the B12 weighting function. The peak's of the B23 and B34 weighting functions lie in a positive lapse rate region and an increase in simulated radiance would occur if the peak rose higher in the atmosphere.

The Chatanika differences (figure 2b) cannot be explained by simply lifting the B23 weighting function's peak but may be the result of a badly interpolated radiance. The observed radiance of 41 RU is equivalent to a black body temperature of -59^{o}C. This appears to be too low considering that the temperature profile minima is only -56^{o}C.

Generally, with the profiles in figures 2a, b and c and with many others drawn, but not shown here, the differences between the observed and simulated radiances can be reduced by assuming that the peak of the weighting functions were higher than originally thought.

An attempt was made to assess the radiometer error by studying the SAT-ROC differences for isothermal profiles. The two most nearly isothermal profiles are shown in figure 4. However, it was found that any true conclusion from these particular profiles was not possible because of the positive and negative lapse rates near the W.F's peak. The differences could then be explained by weighting function changes alone.

Inspection of Table 2 shows that there are considerable differences between sonde types especially in the B12 channel. It appears that the Echosonde (Ryori) has a lower value of SAT-ROC at all levels than the mean Datasonde, indicating perhaps that its temperature measurements are higher than the Datasonde. The mean Russian values are greater than the Datasonde, especially in the B12 channel. This aspect will be discussed in more detail in Section 5.

Of some concern are the West Geirinish results, which show that the UK sonde is similar in performance to the Russian sonde rather than the Datasonde. This is in contradiction to the results of the comparison trials in Kourou in 1973 (Finger et al (1975)). A possible explanation for this anamoly is that, at the time (mid December 1974) when the West Geirinish observations were made, there existed a very strong westerly wind over Scotland. The gradient of the radiance field was also large and the interpolation errors in these conditions would have been particularly large.

West Geirinish's SAT-ROC difference is now being calculated using direct overpasses obtained during the winters of 1975/76 and 1976/77.

4. Regression of stratospheric thicknesses against radiance

Slingo (1976b) has shown that significantly smaller errors are produced by regressing stratospheric thicknesses against the equivalent black body temperatures of several channels than against a single channel (eg Barnett et al (1975)). Consequently 14 thicknesses (100-10, 100-5, 100-2, 100-1, 50-5, 50-2, 50-1, 50-0.3, 20-2, 20-1, 10-1, 10-0.3, 5-1, 5-0.5 mb) were calculated from each temperature profile and each in turn was regressed against the 4 channel black body temperatures. The regression coefficients so found together with the standard error of the estimated thickness are presented in Table 3 (a thickness is calculated by first determining the black body temperature for each radiance, summing the products of the temperature and coefficient and adding the constant A5).

Single channel regression coefficients were also derived for some of the thickness layers used by Barnett (1975). These coefficients are shown in Table 4, with Barnett's figures for comparison. The standard errors found in the present paper are higher than those found by Barnett. This may be a consequence of interpolating the radiance values ie there was no true colocation of rockets with the satellite.

Using the multi-channel regression coefficients, certain stratospheric thicknesses were calculated for all 97 observations. Means and standard deviations of satellite minus rocket (SAT-ROC) thickness differences, for these thicknesses, analysed by rocket sonde station are shown in Table 5.

For the lower stratosphere (100-10 mb) most differences are less than 10 dam. For the upper stratosphere, (5-0.5 mb) the Russian stations (Heiss Island and Volgograd) have large positive differences while the US stations tend to have negative differences.

The last column of Table 5 gives the mean 100-10 mb thickness differences for each station computed using single channel regression (channel A1). Except at Ryori, the multichannel regression technique produces smaller differences and standard deviations, confirming the findings of Slingo (1976b). Only when the stratospheric thickness chosen brackets the peak of the weighting function does the single channel regression technique compare favourably with the multi-channel method.

Figure 5 shows the SAT-ROC differences for 100-10 mb and 5-0.5 mb, for Fort Churchill. The multi-channel regression (MR) differences show less variability and lower mean values especially for the 100-10 mb layer. The mean difference and standard deviation, produced using the single channel (B12) regression coefficients quoted by Barnett et al (1975) are shown for the 5-0.5 mb layer, but for clarity the curve is not drawn. These coefficients (see Table 4) were calculated from data obtained during the period from December 1972 to October 1973. The large mean differences illustrates the importance of accounting for the drift in SCR performance over the intervening 2 years.

The warming reached Fort Churchill in the early part of January 1975. At that time, the SAT-ROC thickness differences from the single channel regression show large changes, indicating that a single channel technique is not really adequate for following properly this major synoptic event.

5. <u>Inter rocket sonde differences</u>

The comparative trials of USA, USSR, French and UK rocket sonde systems at Kourou in 1973 (Finger et al (1975)) showed that the Russian rocket sonde temperature measurements were substantially colder than the rest at high (ie > 50 km) altitudes. Of the 97 rocket profiles used in this paper, 11 are from Russian sondes and 78 are from US Data sondes. A check was made to see if there was any significant difference between these two sonde systems, assuming that over the two month period, the performance of the SCR did not change.

From table 2, the average US and Russian differences of SAT-ROC for each channel (in RU) are shown below;

	B_{12}	B_{23}	B_{34}	A_1
Russian (N=11)	1.3	3.3	3.9	-0.6
US Data Sonde (N=78)	-4.4	0.5	2.1	-0.2
	5.7	2.8	1.8	-0.4

The difference increases with the height of the weighting function's peak and is consistent with the Russian rocket sonde temperatures being colder than the US Data sonde.

If the overall mean SAT-ROC differences are recalculated using Data sondes alone then the effect is to lower all the mean differences, (see Table 2).

Figures 6(a) and (b) show plots of the B12 and A1 measured radiances (SAT) against the simulated (ROC) radiances using the results from Table 1. It can be seen that for the B12 channel, the Russian observations are significantly displaced from the Data sonde ones, but there is little difference in the A1 channel.

6. Changes since 1974/75

Recently Petzoldt (1977) has made a similar comparison using observations from the 1976/77 winter and these are presented in figure 7. The few Russian observations are now well separated from the US Data Sonde results and the SAT-ROC difference between sonde types has increased to 8.7 RU. Part of this difference could be due to using SCR data processed on the day of reception using preliminary calibrations, and part to the weighting function of the B12 channel moving upwards into a region where the temperature bias error between the sondes has a greater effect.

The computed slopes of the regression lines in figures 6(a), (b) and 7 are;

	1974/75		1976/77
	US	Russian	US
B12	0.95	1.00	0.61
A1	0.89	0.91	-

The slope of the regression line for the Data sonde, B12 channel has decreased from 0.95 to 0.61 in 2 years. The two regression lines show only a small change for simulated radiances of 40-45 RU but diverge, so that, at simulated radiances of about 80 RU, the latest (1976/77) observed radiances are some 8 RU lower than the observations of 2 years before. This can be interpreted as further evidence of the upward drift of the level of the peak of the weighting function. When the simulated radiance is low ($\sim$ 40 RU), the temperature is cold at levels near the peak of the weighting function. This occurs when the stratosphere is effectively isothermal and an error in the weighting functions peak pressure level will have little effect on the observed radiances. However, at high simulated radiances, the temperature is high at levels near the peak in the weighting function and the observed radiances will be sensitive to weighting function changes. The reduction of observed radiances during the two years would indicate that the B12 weighting function peak had continued to move upwards to a position above the average stratopause level.

7. Conclusions

During the 1974/75 winter, large differences existed between the radiances measured by the B12 and B34 channels of the Nimbus 5 SCR and the radiances computed from the available weighting functions and radio/rocket sonde temperature profiles. This finding is consistent with the results of other authors and is in agreement with the change in gain of the B channels found by the experimenters (Barnett, 1977). This implies an upward movement of the weighting functions as a consequence of gas leakage from the cells of the SCR.

It has been confirmed that in most circumstances a multi channel regression technique gives significantly smaller errors in retrieving thicknesses than a single channel method. The technique also follows large scale synoptic changes more realistically. However because of degrading of satellite instruments, continual updating of the regression coefficients is required using rocket sonde observations.

In this paper, all available rocket sonde data were used to determine the regression coefficients, using the temperature values reported in the ROCOB messages. However the temperature bias error between the Russian and other types of sonde (Finger et al, 1975) shows up in the results of the regression analysis. In future work, it would be better to correct the Russian observations using the latest available correction factors, before entering them into the regression analysis.

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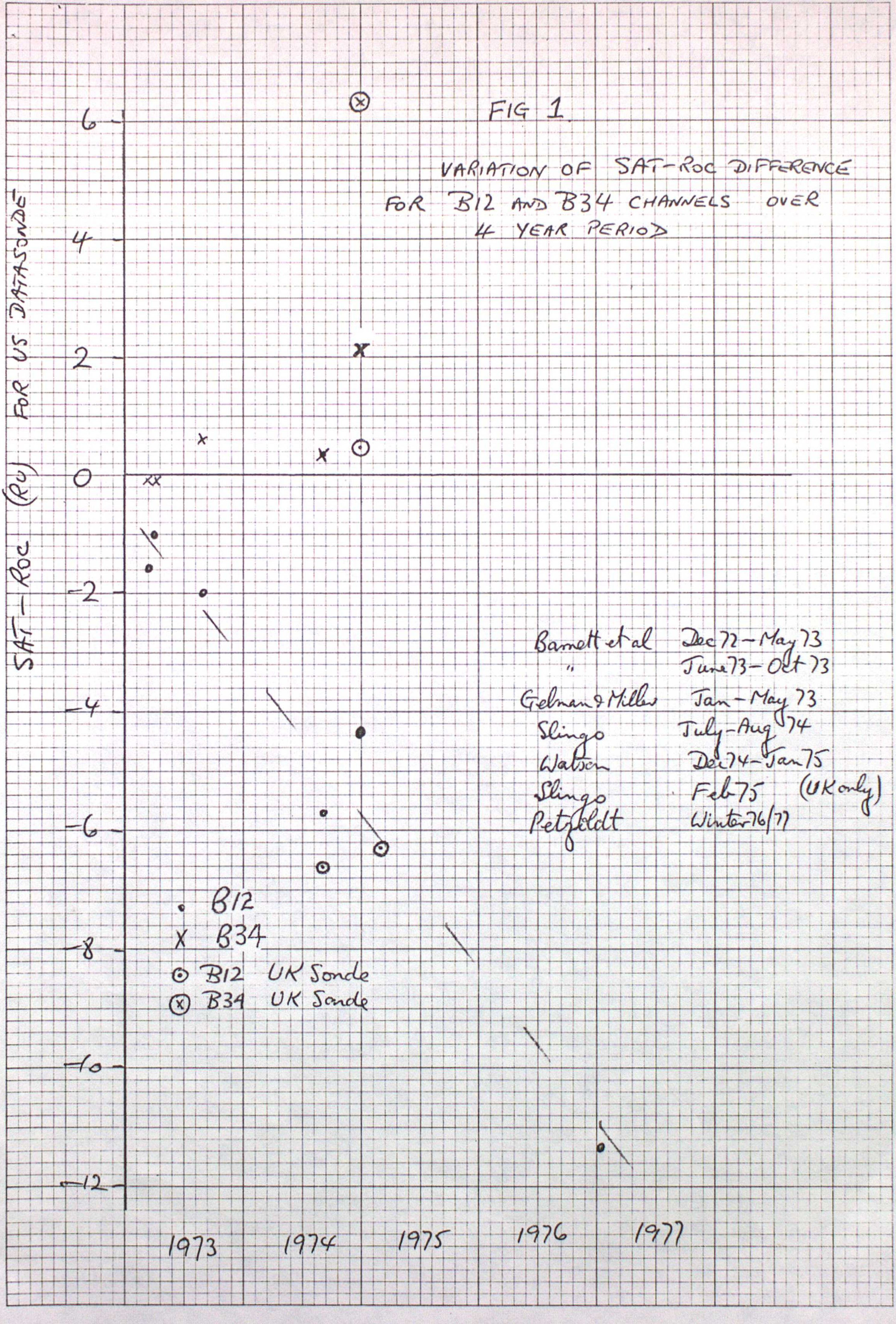
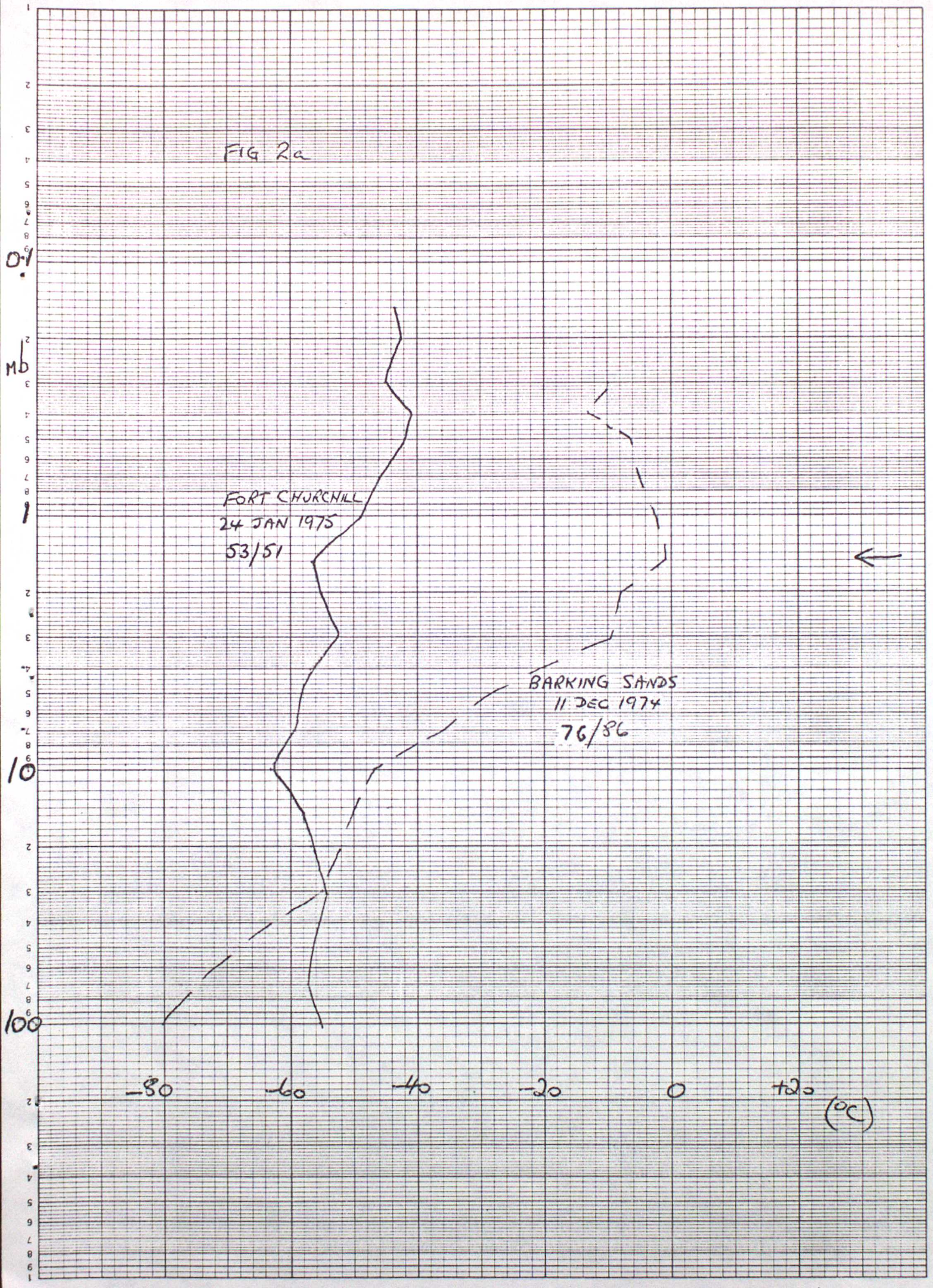


FIG 1

VARIATION OF SAT-ROC DIFFERENCE FOR B12 AND B34 CHANNELS OVER 4 YEAR PERIOD

B12



CHARTWELL
Graph Data Ref. 5555
Log 5 Cycles x 10th, ½ and 1 inch

B23

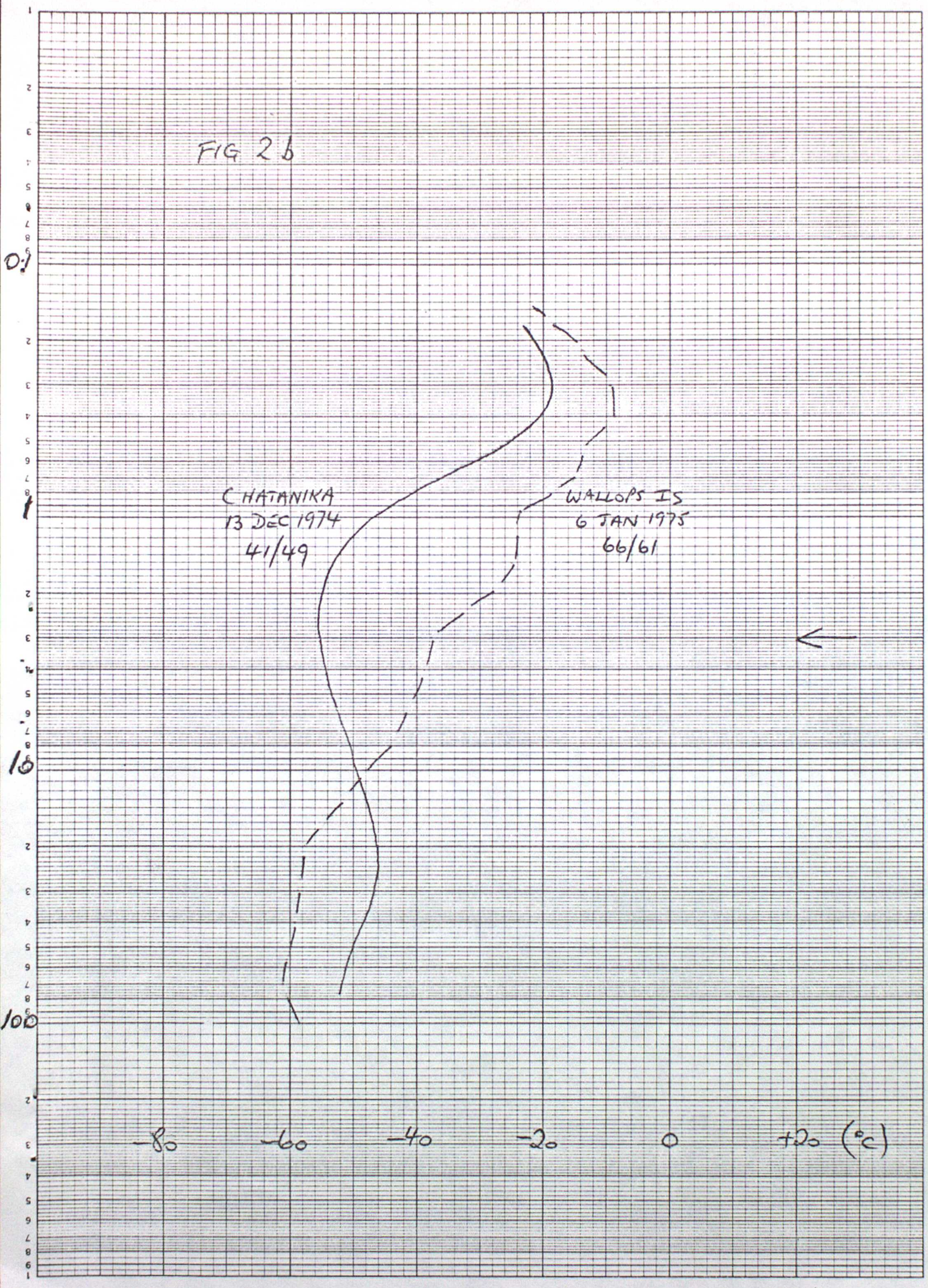


FIG 2b
0.1
1
10
100
CHATANIKA
13 DEC 1974
41/49
WALLOPS IS
6 JAN 1975
66/61
-80
-60
-40
-20
0
+20 (°C)

B34

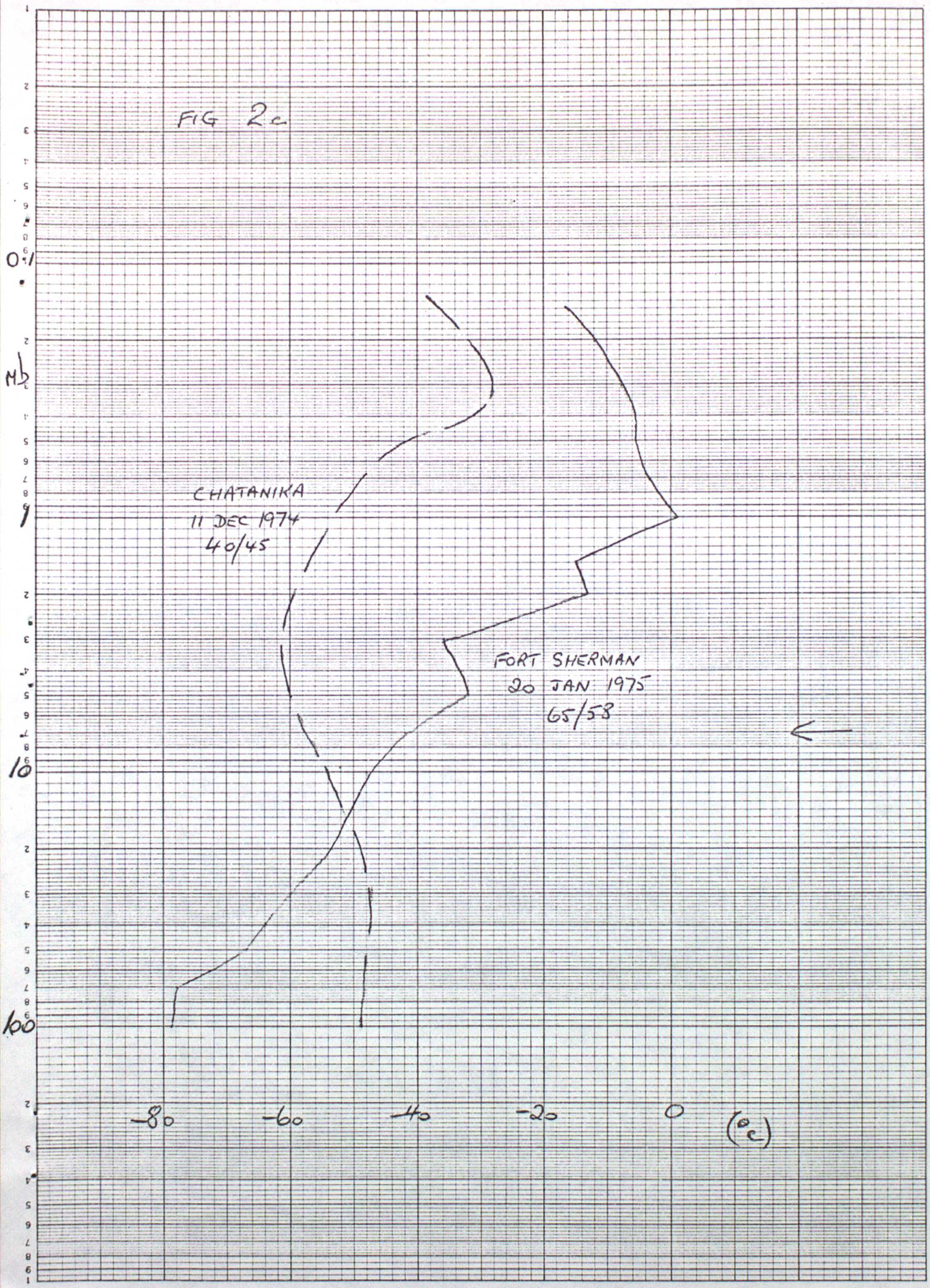


FIG 2c
0·1
Mb
1
10
100
CHATANIKA
11 DEC 1974
40/45
FORT SHERMAN
20 JAN 1975
65/58
-80
-60
-40
-20
0
(°C)

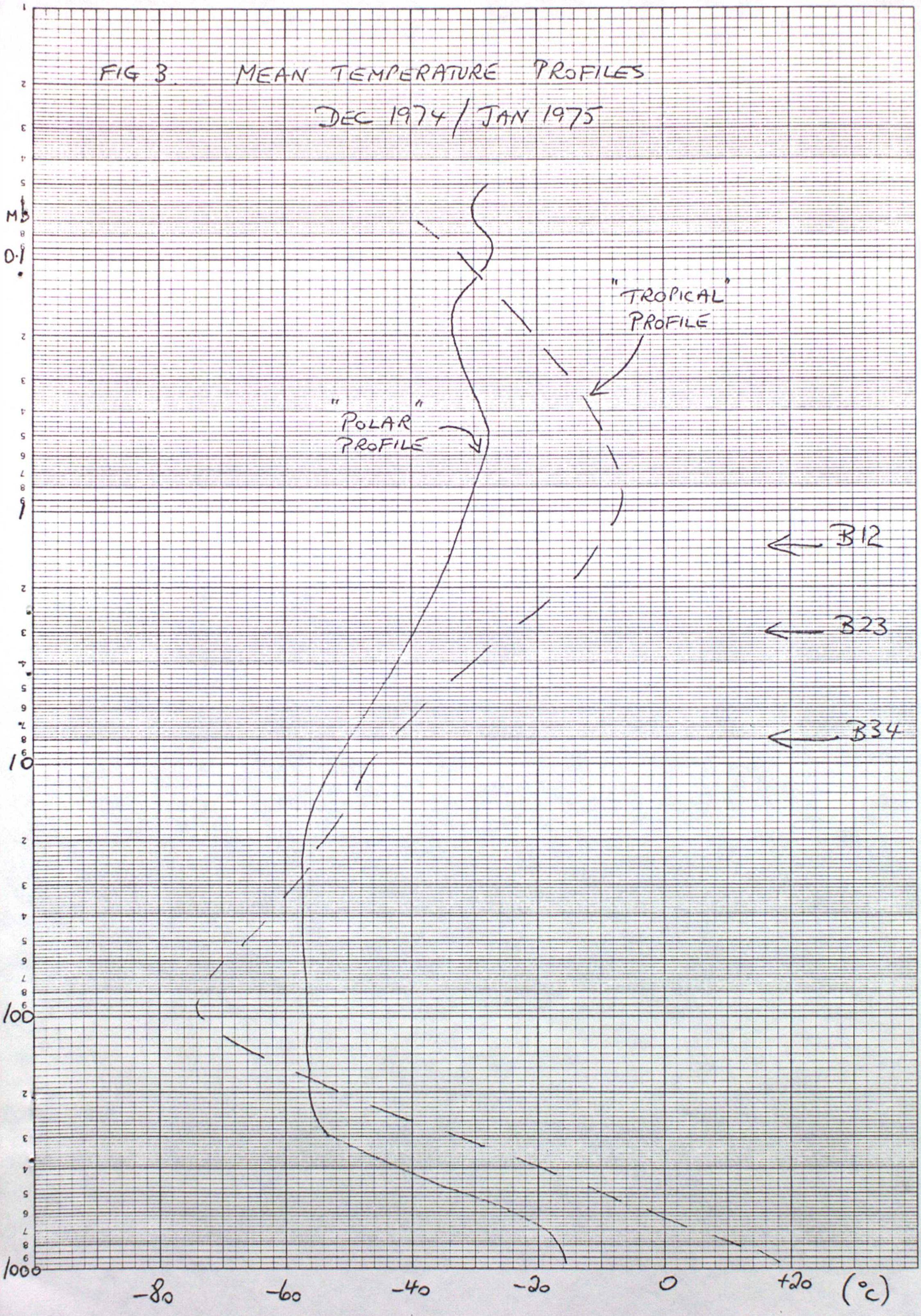


FIG 3. MEAN TEMPERATURE PROFILES
DEC 1974 / JAN 1975
"TROPICAL" PROFILE
"POLAR" PROFILE
B12
B23
B34
MB
0.1
1
10
100
1000
-80
-60
-40
-20
0
+20
(°C)

B12

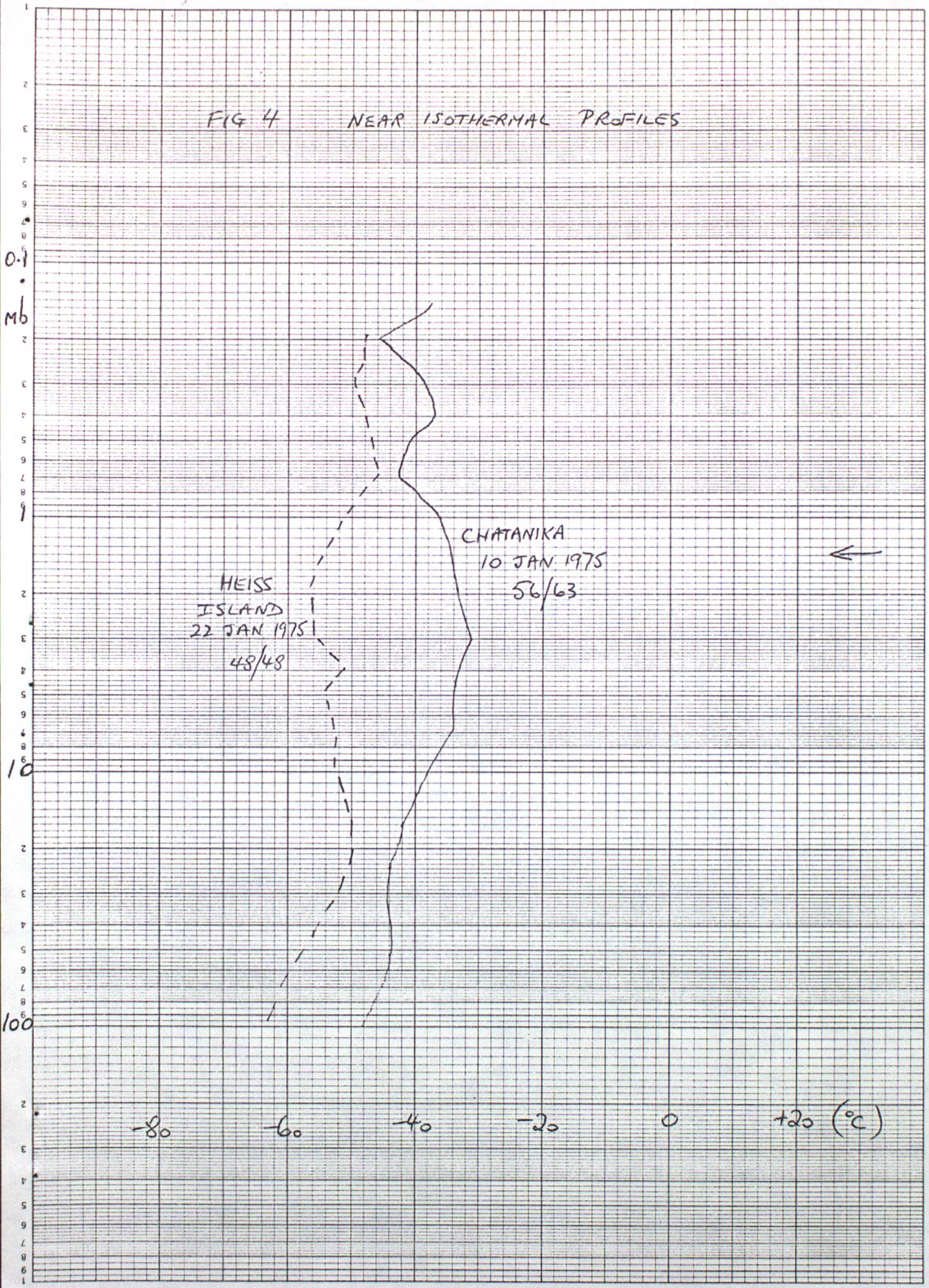
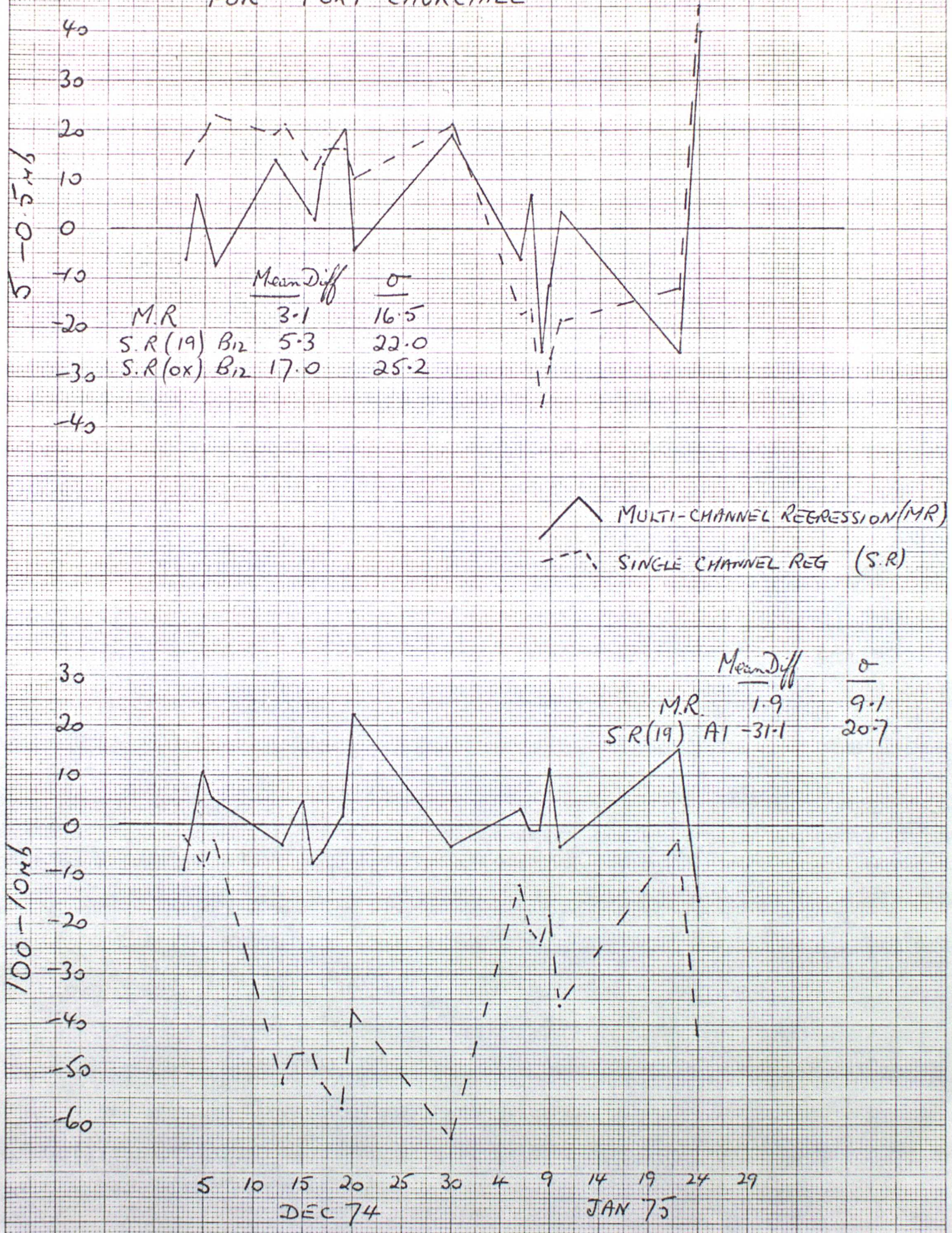


FIG 4 NEAR ISOTHERMAL PROFILES
0.1
mb
1
10
100
CHATANIKA
10 JAN 1975
56/63
HEISS
ISLAND
22 JAN 1975
48/48
-80
-60
-40
-20
0
+20 (°C)

FIG 5.

SATELLITE MINUS ROCKET THICKNESSES (SAT-ROC) FOR FORT CHURCHILL



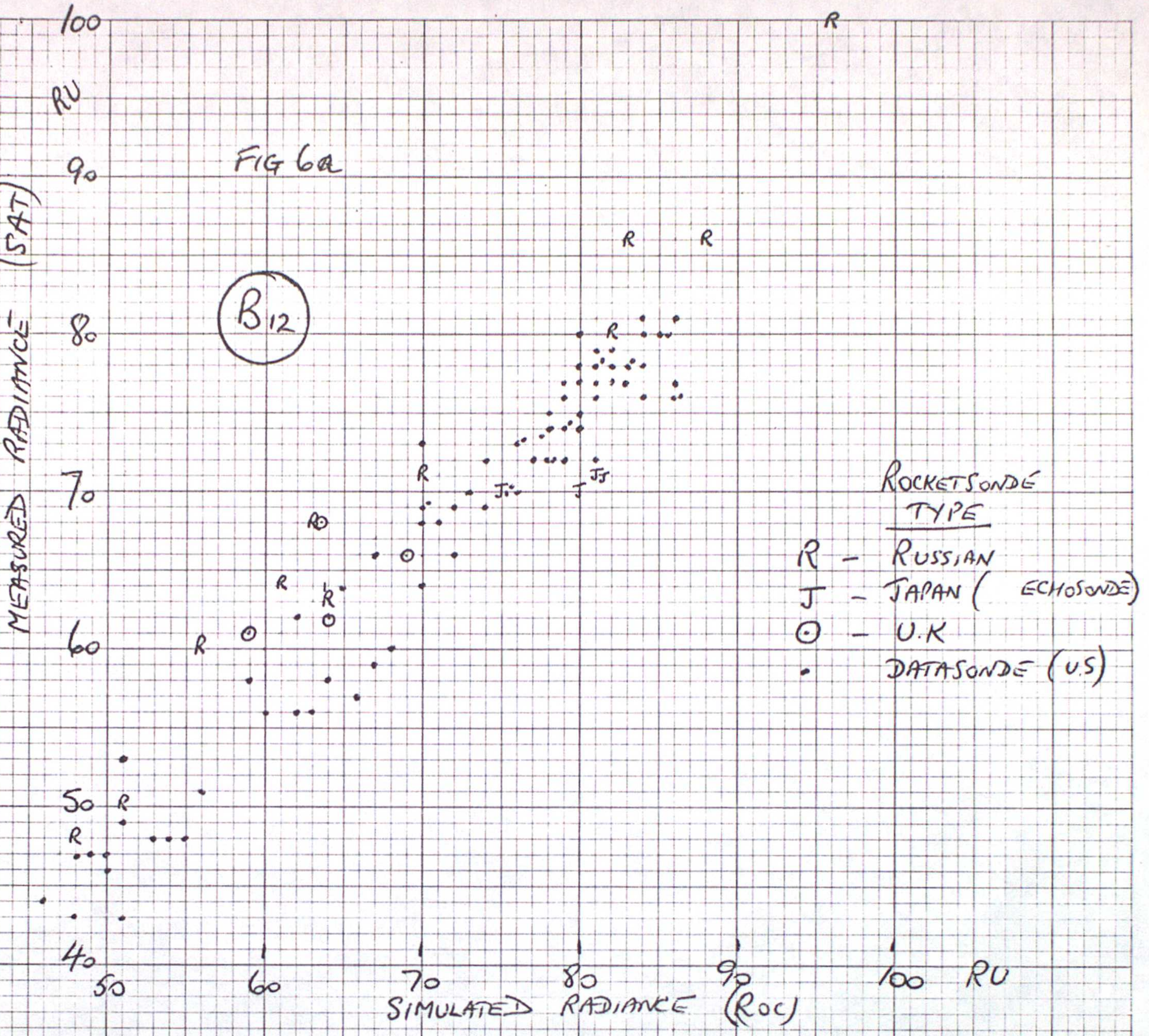


FIG 6a
B12
MEASURED RADIANCE (SAT)
RU
100
90
80
70
60
50
40
50
60
70
80
90
100
RU
SIMULATED RADIANCE (ROC)
ROCKETSONDE TYPE
R - RUSSIAN
J - JAPAN (ECHOSONDE)
⊙ - U.K
• DATASONDE (U.S)

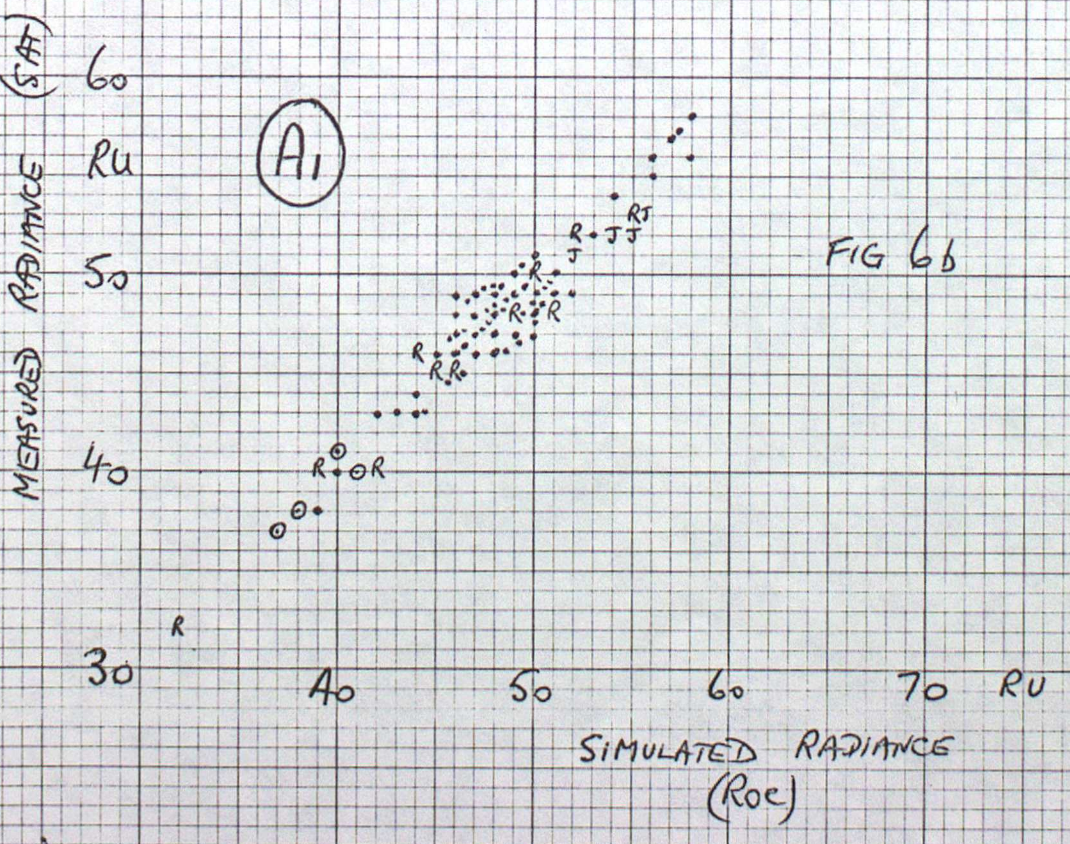
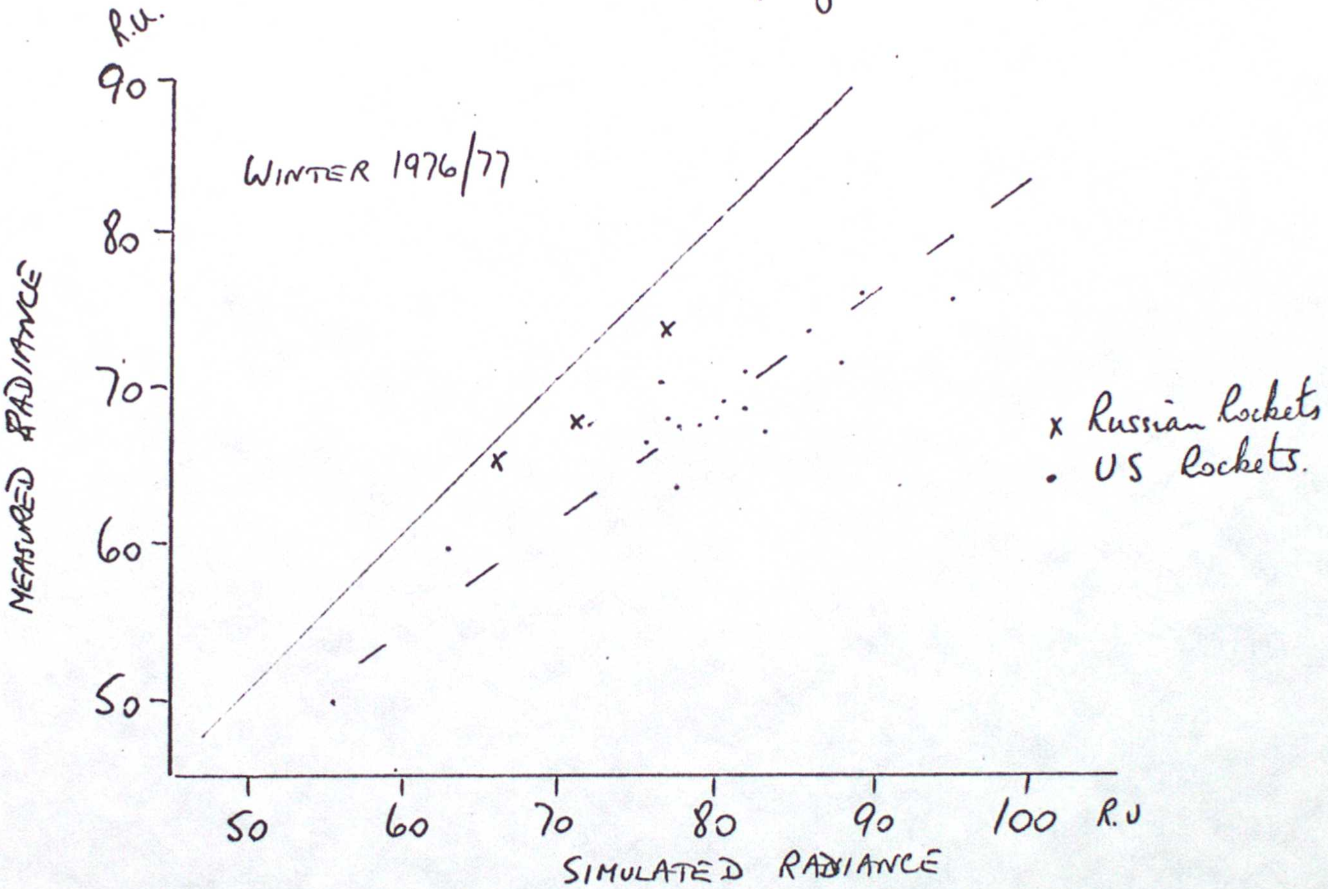


FIG 6b
A1
MEASURED RADIANCE (SAT)
RU
60
50
40
30
40
50
60
70
RU
SIMULATED RADIANCE (ROC)

Measured v. Simulated radiances for Russian and American rockets for B_{12} channel of SCR. (Petzoldt (1977))



Russian Rockets (N=3) $\overline{SAT-ROC}$ = −2.7 RU
U.S. Rockets (N=18) $\overline{SAT-ROC}$ = −11.44 RU

Figure 7

TABLE 1

RADIANCES a) interpolated at rocket stations (top line)
b) simulated from temperature profiles (lower line)

Period: December 1974 – January 1975

units: $mW\,m^{-2}\,ster^{-1}\,(cm^{-1})^{-1}$

STATION	DATE	B_{12}	B_{23}	B_{34}	A_1
HEISS ISLAND	18-12-74	60	48	37	32
		56	44	35	32
80°N	2-1-75	100	103	87	53
58°E		96	98	81	55
	6-1-75	86	90	82	52
		88	86	72	52
	17-1-75	63	59	51	40
		64	59	50	42
	22-1-75	48	49	50	46
		48	46	46	44
	29-1-75	50	48	44	40
		51	46	44	39
CHATANIKA	11-12-74	43	40	40	46
		48	44	45	48
	13-12-74	48	41	49	47
		55	49	49	50
65°N	16-12-74	47	47	52	51
147°W		49	49	51	50
	8-1-75	59	64	63	57
		67	66	62	57
	9-1-75	57	61	62	56
		66	66	63	58
	10-1-75	56	60	59	56
		63	63	61	56
	20-1-75	48	43	46	46
		53	46	45	46
	24-1-75	43	46	47	46
		51	50	50	48
FORT CHURCHILL	3-12-74	62	51	46	43
		62	50	44	42
	5-12-74	58	50	43	40
59°N		59	48	42	40
94°W	6-12-74	64	49	42	38
		65	48	40	39
	12-12-74	47	42	39	43
		48	41	40	44
	13-12-74	49	42	40	44
		51	41	40	44
	16-12-74	51	44	46	45
		56	45	43	46

STATION	DATE	B_{12}	B_{23}	B_{34}	A_1
	17-12-74	47	43	45	45
		50	44	44	46
	19-12-74	44	42	46	47
		46	43	44	46
	20-12-74	48	40	45	49
		54	45	45	47
	30-12-74	46	42	44	47
		50	43	44	48
	6-1-75	66	67	70	58
		72	70	65	59
	7-1-75	64	70	67	57
		70	68	63	57
	8-1-75	60	61	65	55
		68	66	61	56
	9-1-75	58	60	61	54
		64	62	58	54
	10-1-75	56	61	58	52
		62	60	57	53
	22-1-75	56	48	48	43
		60	51	46	43
	24-1-75	53	48	46	43
		51	45	43	44
WEST GEIRINISH	7-12-74	61	51	46	41
		59	47	42	40
57°N	11-12-74	66	55	48	37
		69	54	43	37
07°W	14-12-74	68	58	51	38
		63	51	41	38
	16-12-74	62	55	50	40
		64	52	44	41
VOLGOGRAD	2-12-74	68	64	56	45
		63	59	51	45
	11-12-74	64	60	51	45
49°N		61	55	50	46
44°E	25-12-74	86	81	69	50
		83	75	61	50
	10-1-75	80	78	67	48
		82	78	64	51
	22-1-75	71	64	57	48
		70	62	54	49

RYORI	11-12-74	71	70	65	52
		81	74	65	55
39°N	25-12-74	70	73	68	53
142°E		80	74	65	55
	8-1-75	71	69	63	52
		81	72	63	54
	22-1-75	70	70	63	51
		75	68	59	52
ALLOPS Is	9-12-74	72	69	59	48
		81	72	61	50
	30-12-74	72	62	53	46
38°N		78	63	53	47
75°W	6-1-75	68	66	56	48
		70	61	54	48
	8-1-75	70	70	59	48
		76	67	57	49
	17-1-75	72	71	60	49
		78	67	58	49
	22-1-75	77	76	62	48
		86	76	63	50
	29-1-75	80	75	64	48
		85	75	62	50
MUGU	2-12-74	70	65	57	47
		75	66	57	49
	5-12-74	69	64	55	46
34°N		72	62	54	46
119°W	6-12-74	68	62	55	46
		71	60	52	45
	12-12-74	72	67	59	49
		77	66	57	50
	16-12-74	73	68	58	49
		78	65	56	48
	23-12-74	66	61	55	49
		67	57	53	49
	7-1-75	69	68	59	49
		74	66	57	49
	9-1-75	74	72	63	49
		78	71	60	51
	20-1-75	76	74	63	48
		81	71	59	48
	28-1-75	78	76	65	50
		80	71	54	50
WHITE SANDS	2-12-74	69	68	60	48
		70	63	56	47
	4-12-74	69	66	59	47
32°N		70	65	56	47
106°W	6-12-74	70	68	59	47
		75	65	56	46
	23-1-75	77	75	63	48
		80	71	58	48
BARKING SANDS	9-12-74	76	73	64	48
		84	74	63	49
	11-12-74	76	73	64	49
		86	76	64	50
	12-12-74	77	73	65	49
22°N		83	74	63	50
160°W	13-12-74	76	73	65	49
		86	78	66	52
	16-12-74	77	73	64	49
		79	69	59	47
	17-12-74	77	74	64	49
		82	71	61	48
	18-12-74	79	74	65	49
		82	71	61	48
	20-12-74	78	75	65	49
		83	73	61	49
	23-12-74	75	71	63	48
		80	71	61	48
	24-12-74	74	70	62	48
		79	70	60	48
	26-12-74	72	69	61	47
		79	68	58	47
	7-1-75	74	72	63	47
		79	70	58	47
	17-1-75	78	75	65	48
		82	73	61	48

FORT SHERMAN	2-1-75	70	68	60	47
		73	65	57	46
	7-1-75	72	68	60	48
		74	64	55	46
09°N	8-1-75	73	70	61	47
80°W		76	66	57	46
	17-1-75	76	73	64	49
		79	69	59	48
	20-1-75	79	74	65	49
		83	70	60	48
	28-1-75	80	75	67	50
		84	73	62	49
	30-1-75	81	76	68	50
		84	74	62	49
KWAJALEIN	4-12-74	78	74	66	49
		81	72	63	50
	5-12-74	78	75	66	49
09°N		81	74	63	49
168°E	13-12-74	78	73	65	49
		84	74	63	50
	19-12-74	78	74	66	49
		80	72	62	49
	21-12-74	77	74	65	48
		81	72	62	49
	24-12-74	75	73	64	48
		78	71	61	48
	28-12-74	73	70	62	47
		76	67	59	47
	9-1-75	74	71	62	47
		78	68	59	47
	11-1-75	74	71	63	47
		80	72	62	49
	19-1-75	80	72	66	48
		80	71	61	48
	23-1-75	78	74	66	49
		83	74	63	50
	30-1-75	81	77	67	50
		86	77	66	51

TABLE 2. SAT – ROC DIFFERENCES FOR INDIVIDUAL STATIONS

STATION	TYPE OF ROCKETSONDE	NOS OF PROFILES USED			MEAN MEASURED MINUS SIMULATED (SAT – ROC) R.U.			
		DEC	JAN	TOTAL	B12	B23	B34	A1
HEISS IS	RUSSIAN	1	5	6	0·7	3·0	3·8	-0·2
CHATANIKA	DATASONDE	3	5	8	-6·4	-3·9	-1·0	-1·0
FORT CHURCHILL	"	10	7	17	-3·5	-0·6	1·9	0·3
WEST GEIRINISH	U.K	4	0	4	0·5	3·8	6·3	0
VOLGOGRAD	RUSSIAN	3	2	5	2·0	3·6	4·0	-1·0
RYORI	ECHOSONDE	2	2	4	-8·8	-1·5	1·8	-2·0
WALLOPS ISL	DATASONDE	2	5	7	-6·1	1·1	0·7	-1·1
POINT MUGU	"	6	4	10	-3·8	2·2	1·9	-0·3
WHITE SANDS	"	3	1	4	-2·5	3·3	3·8	0·5
BARKING SANDS	"	11	2	13	-5·8	0·5	2·6	-0·2
FORT SHERMAN	"	0	7	7	-3·1	3·3	4·7	1·1
KWATALEIN	"	7	5	12	-3·7	1·2	2·8	-0·6
				97				
OVERALL MEAN					-3·7	0·9	2·5	-0·3
STANDARD DEVIATION					3·4	3·1	2·5	1·4
DATASONDE MEAN					-4·4	0·5	2·1	-0·2

Channel	B12	B23	B34	A1		
wavenumber cm^{-1} (ν)	668	668	668	669		
Thickness (mb)	a_1	a_2	a_3	a_4	a_5	S.E.
100 − 10	−1.6879	0	−1.8798	10.6599	−76.08	10.1
−5	−2.5678	0	1.4463	10.5361	−138.72	13.4
−2	−3.5707	3.7801	2.4679	9.5755	−182.15	17.2
−1	0	4.9061	0	11.5567	−667.76	21.3
50 − 5	0	0	0	10.0946	−753.96	18.5
−2	0	0	5.5165	7.0230	−708.44	20.0
−1	0	4.5013	3.3901	6.6448	−690.83	21.7
50 − 0.3	9.6063	0	0	11.4365	−1318.49	35.9
20 − 2	−3.1647	4.1775	5.9686	0	−60.77	16.5
−1	0	5.3646	3.8831	1.9073	−534.87	19.5
10 − 1	0	6.4210	2.1017	0	−397.23	17.8
10 − 0.3	8.4437	0	4.0773	0	−469.61	28.5
5 − 1	2.0014	4.5372	0	0	−406.72	16.9
5 − 0.5	6.2537	2.6971	0	0	−477.82	21.3

$$\text{Thickness} = a_1 T_{12} + a_2 T_{23} + a_3 T_{34} + a_4 T_{A_1} + a_5$$

where $$T = \frac{\beta}{\ln\left(\frac{\alpha}{R} + 1\right)}$$ and $\alpha = 1.19094 \times 10^{-5} \nu^3$

$\beta = 1.43879 \nu$

TABLE 3. REGRESSION COEFFICIENTS

TABLE 4. SINGLE CHANNEL REGRESSION COEFFICIENTS

THICKNESS (Mb)	CHANNEL USED	DEC 74 – JAN 75 a	b	S.E	(from Barnett et al (1975)) DEC 72 – OCT 73 a	b	S.E
10–1	B23	7.94	–270	19.0	7.01	–28	16.5
10–0.3	B12	11.17	–181	35.5	10.90	–106	18.3
50–0.3	B23	10.73	987	47.6	10.17	1174	25.3
5–0.5	B12	8.97	–492	23.6	8.32	–331	16.7
100–1	B34	10.30	674	33.3	10.70	630	24.4
100–10	A1	7.30	–173	30.7	–	–	–

THICKNESS (dam) = aT + b

TABLE 5.

SATELLITE MINUS ROCKET THICKNESSES (dam)

	MULTI-CHANNEL												SINGLE CHANNEL (A1)		
	100–10			10–1			100–1			5–0.5			100–10		
	Mean	(n)	σ	Mean	(n)	σ	Mean	(n)	σ	Mean	(n)	σ	Mean	(n)	σ
HEISS ISLAND	9.0	(6)	13.8	0.8	(6)	24.6	3.8	(6)	32.5	35.3	(6)	36.7	22.1	(6)	51.9
CHATANIKA	-1.3	(8)	12.4	-14.2	(8)	13.0	-19.0	(8)	21.2	-9.0	(8)	13.9	-49.5	(8)	17.7
FORT CHURCHILL	1.9	(17)	9.1	3.5	(17)	17.2	6.2	(17)	13.8	3.1	(17)	16.5	-31.1	(17)	20.7
WEST GEIRINISH	4.3	(4)	11.0	1.4	(4)	17.0	7.2	(4)	20.5	-0.2	(4)	22.5	15.8	(4)	24.8
VOLGOGRAD	-6.5	(5)	9.6	1.4	(5)	17.5	-4.1	(5)	20.3	18.7	(5)	13.4	8.5	(5)	27.9
RYORI	-8.8	(4)	6.2	-8.5	(4)	14.0	-19.1	(4)	15.1	-23.7	(4)	18.7	-5.2	(4)	5.2
WALLOPS IS.	-0.7	(7)	6.2	-14.0	(7)	25.2	-14.7	(7)	25.9	-20.4	(6)	24.9	9.5	(7)	10.0
POINT MUGU	-1.2	(10)	12.1	2.5	(10)	15.2	3.5	(10)	20.8	-4.4	(10)	16.1	6.2	(10)	17.1
WHITE SANDS	10.1	(4)	4.9	8.2	(4)	11.4	15.9	(4)	13.4	3.9	(4)	13.5	21.4	(4)	8.2
BARKING SANDS	-2.3	(13)	7.6	-9.1	(13)	14.6	-6.7	(13)	20.2	-18.9	(13)	15.6	23.5	(13)	8.5
FORT SHERMAN	5.9	(7)	5.7	17.0	(7)	15.0	25.3	(7)	13.7	10.9	(7)	5.7	25.6	(7)	9.0
KWAJALEIN	-10.8	(12)	5.9	-3.8	(12)	18.6	-8.0	(12)	11.7	4.0	(11)	12.5	13.7	(12)	5.8