LONDON, METEOROLOGICAL OFFICE.

Met.O.19 Branch Memorandum No.13.

A relationship between errors in the SIRS soundings of various thicknesses and errors in the 1000 mb temperature. By MAY, B.R.

London, Met.Off., Met.O.19 Branch Mem.No.13, [1975], 31cm.Pp.7, pls.3.Abs.p.l.

Met O 19 Branch Memorandum (No 13)

A relationship between errors in the SIRS soundings of various thicknesses and errors in the 1000 mb temperature

B R May

JS

HA/29/14

A RELATIONSHIP BETWEEN ERRORS IN THE SIRS SOUNDINGS OF VARIOUS THICKNESSES AND ERRORS IN THE 1000mb TEMPERATURE

by B R MAY

ABSTRACT

It is shown that there is a close relationship between the deviation from the true (radio-sonde) values of the SIRS soundings of the thickness of the 1000-700, 1000-500 and the 1000-300mb layers and the deviation of the 1000mb temperature. This relationship could be used to correct erroneous SIRS thicknesses if adequately accurate values of the true 1000mb temperature were available.

1) Introduction:

Since July 1973 the Meteorological Office has been receiving the SIRS upper-air soundings from NESS (the National Environmental Satellite Service, Washington) via the Global Telecommunication system. The SIRS soundings are temperature and thickness profiles retrieved from observations of radiance made by the Vertical Temperature Profile Radiometer (VTPRs) on the NOAA2 and NOAA3 operational space-craft. For a complete description of the VTPR instrument and the characteristics of the SIRS soundings see NESS report 65, or for a shorter description see the Met O 19 report HA/IG/6.

May (Met O 19 report HA/IG/5) has previously described some results from a small-scale comparison of SIRS soundings and co-located sonde soundings. This note which presents the first and rather tentative results from a larger-scale comparison recently started by Met O 19, concerns the possibility of improving the SIRS retrievals of certain important thicknesses by a comparison of the true and retrieved 1000mb temperatures.

The principles adopted for choosing the co-located SIRS and sonde soundings are described in report HA/IG/6 with the following changes:

i) The maximum distance apart allowed between the nominal positions of the SIRS and sonde soundings has been reduced to 1°5 (≃170 km),

ii) Due to improvements in the methods of determining the co-located soundings a greater number of comparisons per day (≃15) are made, using a greater diversity of types of sonde and also covering a larger geographical area.

The results in this note are based on 162 world-wide comparisons covering the period [illegible]/22^{h} UT on October 1 to [illegible] 23^{h} UT on October 12 1973: during this period instrument 1 on NOAA2 spacecraft was in use.

2) Object of the Analysis

As described in the report NESS 65 the mean clear radiances for areas approximately 500 km square are deduced from the basic "cloudy" radiances measured by the VTPR. These radiances are then used to retrieve the atmospheric vertical temperature and thickness profile from 1000 mb to 10 mb using a retrieval method which requires a first guess temperature profile. As the first guess NESS use various combinations of forecast and climatological profiles and the previous days' analysis, depending upon the height range and the geographical region. It is well known that for a given set of clear radiances no unique temperature profile exists (due to the finite vertical extent of the weighting functions) so that, in general it is possible to constrain the solution temperature profile to have a specified temperature at a specified level. Moreover because there is a certain degree of correlation between retrieved temperatures at neighbouring levels in the atmosphere (because the vertical resolving power of the radiometer is too poor for the temperature at close levels of the atmosphere to be altered independently) the effect of constraining the temperature on one level inevitably influences the temperature on neighbouring levels though the strength of the influence gradually weakens with increased vertical distance.

Over the oceans, the only region for which the SIRS soundings are currently produced, the amount of upper-air sonde data is small. This is certainly true for the Northern Atlantic especially since the removal of the American Weather ships but on the other hand there are relatively large numbers of surface observations, and in particular surface air temperature, made each day by ships in the busy transatlantic shipping lanes. Assuming that the surface air temperature can be used to estimate the 1000 mb temperature (the lowest level for which the SIRS temperatures are produced) then this temperature is the most reasonable one to use to constrain the retrieval of the profile from VTPR observations.

The retrieved SIRS 1000 mb temperatures are not deliberately contrained to have any particular values and, in general, are not in agreement with the "true" 1000 mb temperatures from the co-located sondes.

The histogram of occurrences of ΔT_{1000} (in the sense SIRS- SONDE) is shown in figure 1 in which nearly 50% of the differences lie within the range $\pm 2^{\circ}C$, 79% lie with the range $\pm 4^{\circ}C$ and some differences are as large as $\pm 10^{\circ}C$. Now for our sample of SIRS soundings it is not possible to infer the temperature and thickness profiles that would have been retrieved had the retrieved 1000 mb temperatures been constrained to agree with those measured by the co-located sondes. However it can safely be assumed that had the retrieved 1000 mb temperatures been constrained to the values which actually resulted from the unconstrained retrieval then the resulting constrained temperature profiles would have been identical to the unconstrained profiles. Thus the unconstrained SIRS retrievals can be regarded as being constrained retrievals in which the specified 1000 mb temperatures differ from the true (sonde) values by known amounts which are usually non-zero. Using this principle the relationship between errors in the thickness and errors in the 1000 mb temperatures can be established. In this work the 1000-700, 1000-500, 1000-300, 1000-100 mb thicknesses have been used.

3) Results of the Analysis

Because of the high positive correlation which exists between retrieved temperatures at neighbouring levels the errors in these thicknesses are correlated with the error in the 1000 mb temperature. This is shown by the results in figure 2 where, for the four thicknesses, the mean Δ th for the comparisons whose ΔT_{1000} lie in the ranges -9.1°C to -11.0°C (labelled -10°C in the figure) to +5.0°C to +6.9°C (+6°C in the figure) are plotted with their standard error bars. These data are also shown in tabular form in table 1 along with the number of observations in each range of ΔT_{1000}, their sds and the se of the sd. For all the thicknesses there is definite variation of Δ th with ΔT_{1000} though the nature of the variation is less clear for the 1000-100 mb layer than for the other layers. For both the 1000-700 and the 1000-300 mb layers the trend line (drawn by eye) passes close to the origin indicating that there is a negligible bias in their retrieved thickness, but for the 1000-500 and the 1000-100 mb layers the biases are about -1dm and -5dm respectively. The standard deviations of the thicknesses about the trend lines (the "unexplained" sd) are estimated to be 1.5, 2.5, 3.6 and 5.5 dm respectively for the layers in order of increasing thickness, compared with the standard deviation from the original thicknesses, of 2.4, 3.4, 4.2 and 5.7 dm.

For the two narrower layers there is a useful improvement in the variability of Δth to be gained if the correction ΔT_{1000} can be estimated with sufficient accuracy - for the remaining layers the improvement would be of marginal or negligible value. Even if it were thought to be not worthwhile attempting to correct all SIRS thicknesses in this way then certainly some very bad SIRS soundings could be eliminated by a search for extreme values of ΔT_{1000}.

The results just described have an immediate application in forecasting (providing suitable estimates of the "true" 1000 mb temperatures are available) but the results of the comparison can also be presented in a slightly different way to demonstrate the improvement in the variability of Δth that could be achieved for different precisions with which the true 1000 mb temperature can be estimated. The results of this analysis are shown in figure 3 in which are plotted the standard deviations (along with their standard error bars) of the Δth's for all comparisons whose ΔT_{1000} lie in the range $\pm 1^{\circ}$C, $\pm 2^{\circ}$C .... up to $\pm 7^{\circ}$C and finally for all values of ΔT_{1000}; the results are also tabulated in table 2. For the 1000-700 mb layer, s increases steadily from 1.27 dm (se of s = 0.20 dm) for the $\pm 1^{\circ}$C range in ΔT_{1000} to 2.12 dm (0.18 dm) for = $\pm 7^{\circ}$C range and to 2.39 dm (0.19 dm) for all soundings. For the 1000-500 mb thickness, the same trend of increasing s with enlarging range of ΔT_{1000} is observed, from 2.11 dm (0.25 dm) for $\pm 1^{\circ}$C to 3.41 (0.19 dm) for all points. The sd of the 1000-300 mb thickness shows a slight increase with temperature range from 3.41 dm (0.37) to 4.23 dm (0.23 dm) for all soundings but for the 1000-100 mb thickness, the increase in s is negligible. It appears that if the 1000 mb temperature retrieved from VTPR observations can be made to agree with the true temperature to within, say, $\pm 2^{\circ}$C then the sd of the difference between the true and retrieved 1000-700 mb and 1000-500 mb thicknesses can be reduced by 38 and 25% respectively, from the sd which occurs when no constraints are applied.

Finally it must be stressed that these results apply only to VTPR instrument 1 on NOAA 2 spacecraft - for other VTPRs different statistics (especially the thickness bias) are appropriate.

Acknowledgement:-

I would like to acknowledge the assistance of J Humphreys in the preparation of the SIRS-SONDE comparison data.

T A B L E 1

Range ΔT_{1000}	1000 - 700 mb			1000 - 500 mb			1000 - 300 mb			1000 - 100 mb		
	N	$\overline{\Delta th}$ (se)	S(se)	N	$\overline{\Delta th}$ (se)	S(se)	N	$\overline{\Delta th}$ (se)	S(se)	N	$\overline{\Delta th}$ (se)	S(se)
+6.9 to +5.0	7	+2.93(0.24)	0.64(0.17)	7	+2.40(0.41)	1.08(0.29)	7	+2.78(0.68)	2.33(0.62)	7	-2.89(1.44)	3.82(1.02)
+4.9 to +3.0	12	+1.46(0.51)	1.78(0.36)	12	+1.49(0.55)	2.70(0.78)	12	+2.08(1.36)	4.70(0.96)	12	-4.68(1.28)	4.44(0.91)
+2.9 to +1.0	35	+1.49(0.28)	1.63(0.20)	36	+1.14(0.44)	2.64(0.31)	36	+1.31(0.56)	3.33(0.39)	33	-4.04(0.99)	5.67(0.70)
+0.9 to -1.0	43	-0.18(0.19)	1.27(0.14)	42	-0.84(0.33)	2.08(0.23)	42	+0.18(0.54)	3.45(0.38)	33	-3.85(0.89)	5.13(0.63)
-1.1 to -3.0	32	-1.22(0.18)	1.02(0.13)	31	-2.45(0.37)	2.04(0.26)	31	-2.00(0.50)	2.79(0.35)	28	-8.11(0.96)	5.07(0.68)
-3.1 to -5.0	12	-3.26(0.36)	1.25(0.25)	12	-5.08(0.78)	2.72(0.56)	12	-4.25(1.04)	3.61(0.74)	9	-8.91(1.75)	5.24(1.24)
-5.1 to -7.0	9	-2.78(0.52)	1.57(0.37)	9	-3.88(0.99)	2.96(0.70)	9	-3.49(1.44)	4.31(1.02)	9	-6.82(2.32)	6.97(1.64)
-7.1 to -9.0	6	-4.52(0.67)	1.51(0.47)	6	-6.43(1.78)	4.37(1.26)	6	-4.77(1.65)	4.05(1.17)	5	-9.22(2.25)	5.03(1.59)
-9.1 to -11.0	4	-5.07(0.55)	0.95(0.39)	4	-6.23(1.16)	3.27(1.64)	4	-5.73(2.88)	5.74(2.03)	-	-	-

Units: ΔT_{1000}, °C; $\overline{\Delta th}$ and s, g p d m

Differences in the sense (SIRS-SONDE)

TABLE 2

Range ΔT_{1000}	1000-700 mb		1000-500 mb		1000-300 mb		1000-100 mb	
	N	S(se)	N	S(se)	N	S(se)	N	S(se)
+1.0 to -1.0	43	1.27(0.14)	44	2.11(0.23)	44	3.41(0.37)	36	5.02(0.60)
+2.0 to -2.0	83	1.48(0.11)	84	2.52(0.20)	84	3.56(0.28)	71	5.64(0.48)
+3.0 to -3.0	110	1.68(0.11)	111	2.69(0.18)	111	3.46(0.23)	97	5.68(0.41)
+4.0 to -4.0	128	1.87(0.12)	129	2.98(0.18)	129	3.64(0.23)	113	5.75(0.38)
+5.0 to -5.0	132	1.96(0.12)	133	3.13(0.19)	133	3.92(0.24)	116	5.69(0.38)
+6.0 to -6.0	141	2,09(0.13)	142	3.20(0.19)	142	3.95(0.23)	125	5.73(0.36)
+7.0 to -7.0	145	2.12(0.13)	146	3.23(0.19)	146	3.95(0.23)	129	5.79(0.36)
ALL	158	2.39(0.14)	162	3.41(0.19)	162	4.23(0.23)	142	5.72(0.34)

Units:- ΔT_{1000}, ^{o}C; s, g p d m

Differences in the sense (SIRS-SONDE)

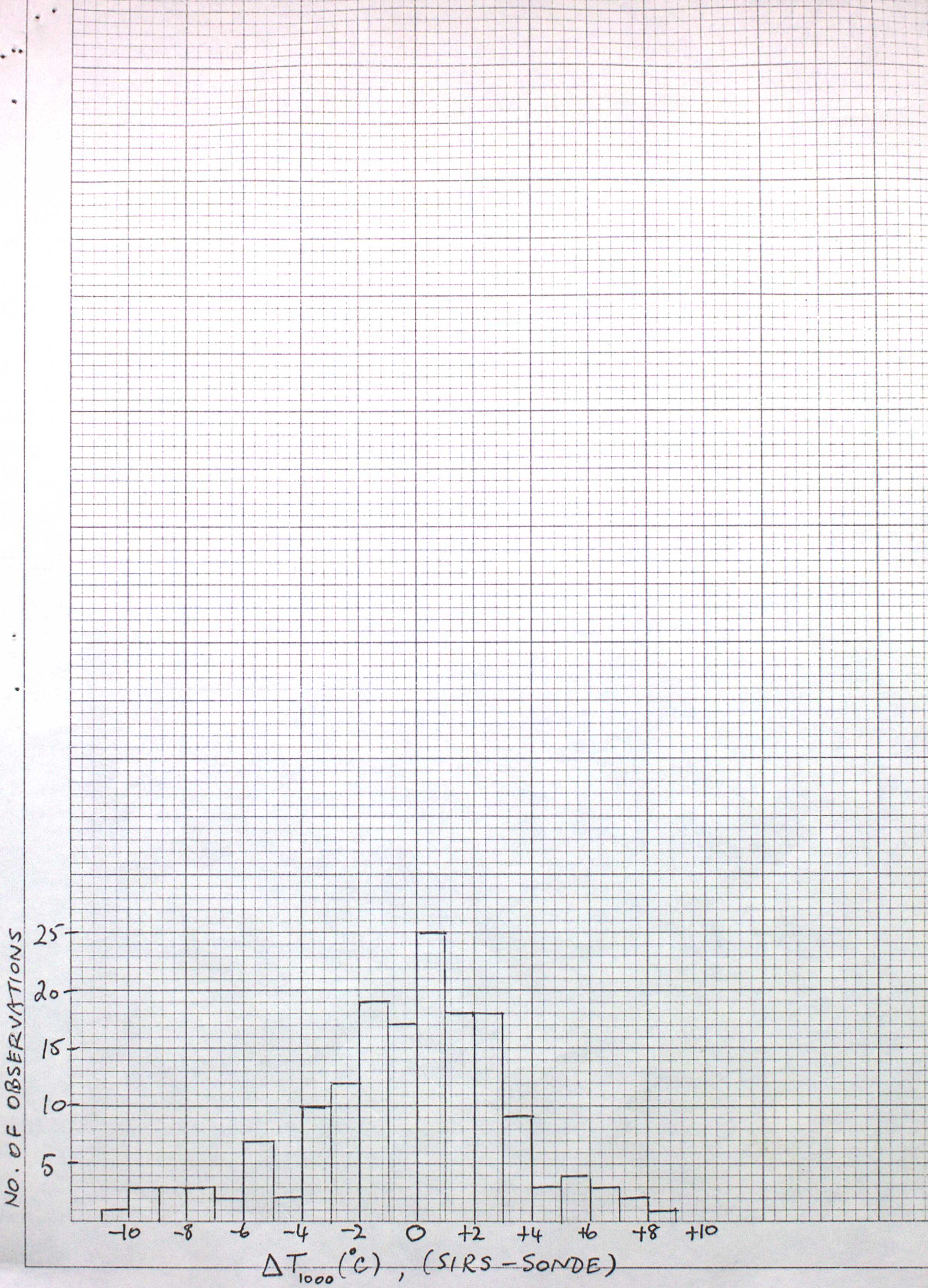
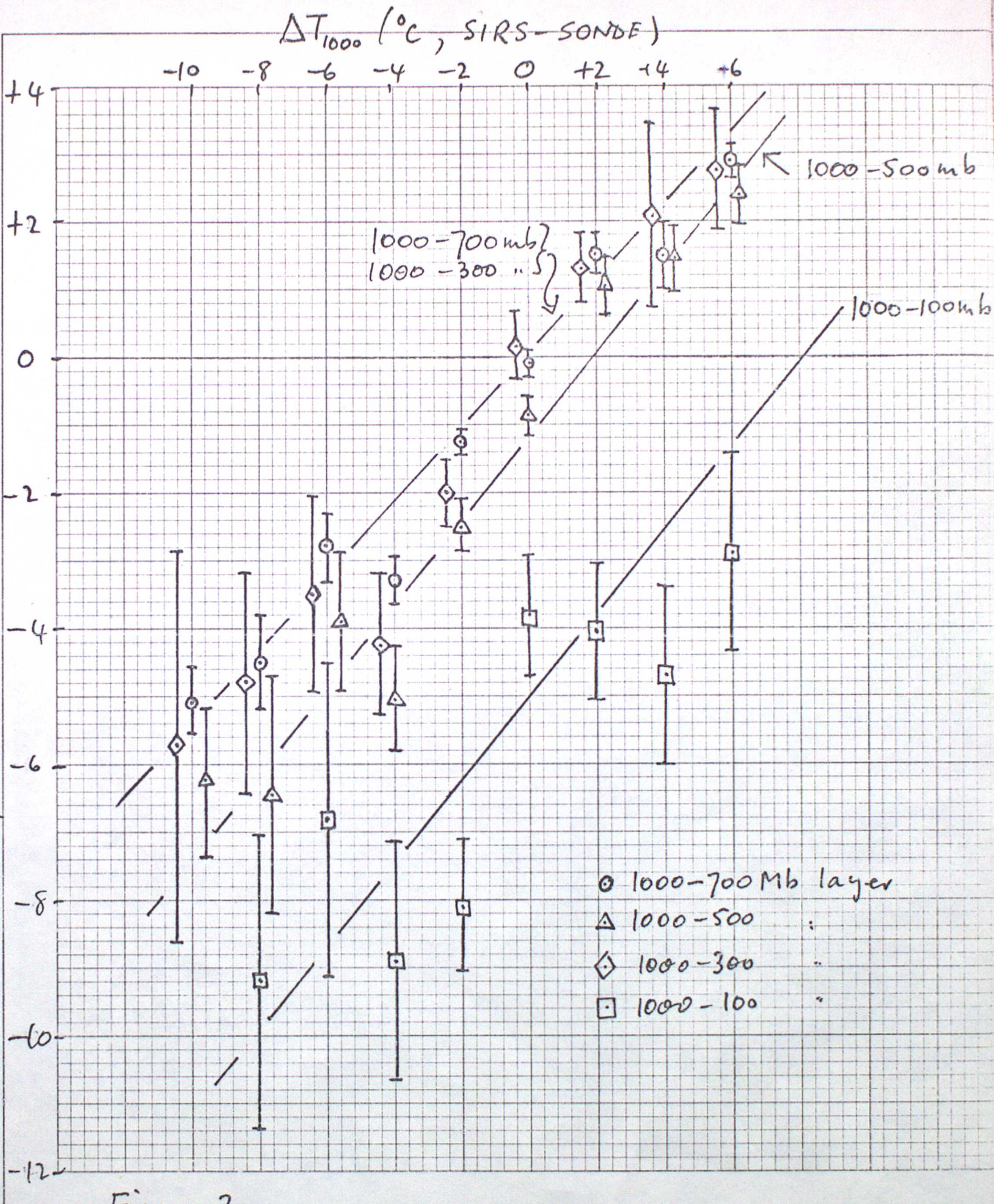
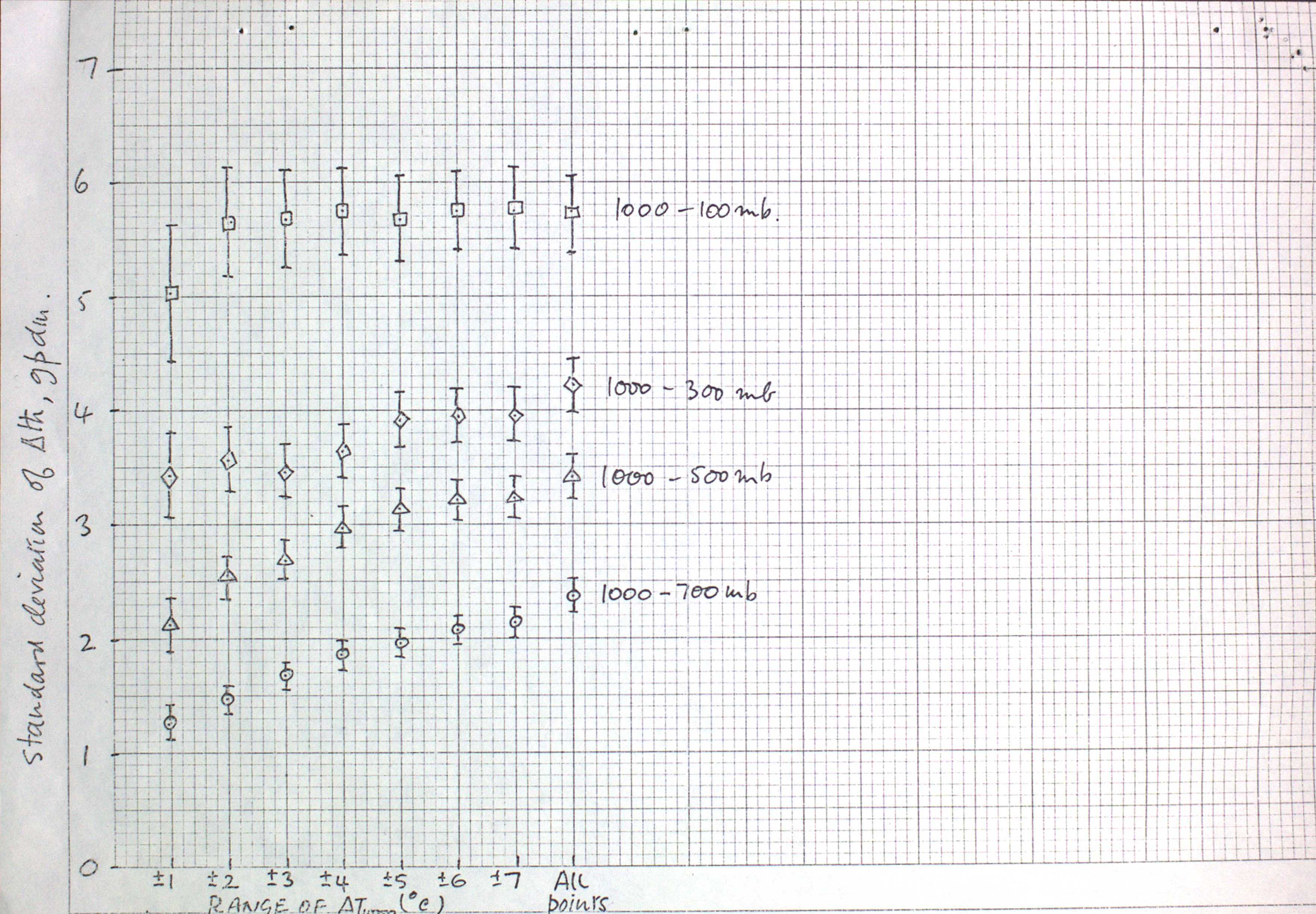

NO. OF OBSERVATIONS
25
20
15
10
5
-10
-8
-6
-4
-2
0
+2
+4
+6
+8
+10
ΔT1000 (°C), (SIRS – SONDE)

FIGURE 1



ΔT1000 (°C, SIRS-SONDE)
-10
-8
-6
-4
-2
0
+2
+4
+6
+4
+2
0
-2
-4
-6
-8
-10
-12
ΔH (gpdm, SIRS-SONDE)
1000-500mb
1000-700mb
1000-300 ..
1000-100mb
1000-700Mb layer
1000-500
1000-300
1000-100

Figure 2



standard deviation of Δth, gpdm.
7
6
5
4
3
2
1
0
±1
±2
±3
±4
±5
±6
±7
All points
RANGE OF AT_{1000} (°c)
1000 - 100 mb.
1000 - 300 mb
1000 - 500 mb
1000 - 700 mb

Figure 3