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B R May

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RESULTS OF A COMPARISON OF SIRS AND RADIO-SONDE UPPER-AIR SOUNDINGS

by B R MAY

HA/IG/5

1) Introduction

Since the beginning of 1973 the Meteorological Office has been receiving the "SIRS" soundings of upper-air temperature and heights which are deduced from the radiance measurements made by the Vertical Temperature Profile Radiometers (VTPRs) on the NOAA 2 and NOAA 3 spacecraft. The intention is that the SIRS soundings should supplement conventional radio-sonde soundings, but they are different from them in at least four respects:-

- a) SIRS soundings are confined to sea areas, while radio-sonde soundings are mainly concentrated over land.
- b) SIRS soundings are average temperatures and heights over considerable areas compared to the "point" observations made by radio-sondes.
- c) Radio-sonde observations are made near the synoptic hours 00 and 12Z whereas the SIRS soundings are a synoptic.
- d) A single VTPR instrument makes all the measurements over the atmosphere while a large number of (and also types of) radio-sondes are used.

The value of the SIRS soundings can be assessed by using them along with radio-sonde observations in elaborate numerical objective analysis schemes and forecasting models which can exploit their particular distribution in location and time. However there is some benefit to be gained by making direct comparisons of near-coincident SIRS and radio-sonde soundings. This note describes the results obtained from a small-scale comparison of soundings during October and November 1973.

2) Description of the SIRS soundings.

The VTPR, of which there are two in each of the NOAA2 and NOAA 3 spacecraft, was designed by NESS (National Environmental Satellite Service) of the USA who are also responsible for the retrieval of the SIRS soundings from the radiance measurements. The NOAA spacecraft are in sun-synchronous 1500 km high polar

orbits which enables the VTPRs to make observations of the atmosphere twice per day at latitudes greater than 50° , and the remainder of the atmosphere usually once per day. For the NOAA 2 spacecraft, which was operational up to mid-March 1974, the local time of the observations near the equator and mid-latitudes were about 09 and 21 hours, while for the NOAA 3 spacecraft (the present operational one) the times are 0830 and 2030 hours.

The VTPR is a multi-channel radiometer observing the Earth's surface and atmosphere in eight narrow bands in the infra-red spectrum. Six of the channels are in the 15μ CO₂ spectral band, one in the water-vapour band near 20μ , and the remaining one is in the atmospheric "window" near 11μ . The radiances measured in the six CO₂ channels are used to determine the vertical temperature profile of the atmosphere, while the radiance in the single water-vapour channel can be used to deduce rough estimates of the humidity mixing ratio but this information is not transmitted in the SIRS message. The window channel radiance is used along with the cross-track scanning facility of the VTPR to over-come the problem of sounding in partly ^{cloudy} areas.

The radiances measured by the VTPR CO₂ channels do not come from a single level of the atmosphere but are emitted by broad overlapping bands defined by the weighting functions which are centred at levels from 40mb (for channel 1) to the surface (for channel 6). This leads to a poor vertical resolving power which results in the radiances from the channels peaking close to the surface consisting of two components. One component comes from the surface and the other comes from the atmosphere itself, from which the temperature profile is deduced. The surface contribution depends upon the surface temperature and emissivity and it is only for the sea-surface that these are known with adequate accuracy. The SIRS observations therefore are confined to the sea areas. The breadth of the weighting functions also cause the SIRS soundings to be non-unique in that a set of measured radiances can give rise to many different temperatures profiles. The method of retrieval used by NESS ensures that the deduced temperature profile

is meteorologically "reasonable" by constraining it to be similar to a first guess profile (usually a computer forecast profile). The contamination of the radiances by clouds also presents a considerable problem. This has been overcome by NESS for partly-cloudy areas at least by using the cross-track scan of the VTPR to observe the variability of radiance due to the cloud in an area (roughly 500 km by 500 km) over which it is assumed the temperature profile and cloud-top height are uniform. The result of this is that the SIRS soundings are actually mean values of temperature and thickness over 500 km squares although they are attributed to single geographical locations. These are arranged in rows of three across the spacecraft track, but some may be displaced or missing due to excessive cloud.

The product of the retrieval process is a profile of temperature and hence thickness as a function of pressure, from which NESS produce the final form of the SIRS sounding by adopting a suitable reference pressure height.

The techniques used by NESS to produce the SIRS soundings are described more fully in a NOAA Technical Report. (ref. 1).

3) The comparison of SIRS and radio-sonde soundings.

The comparison was made between thicknesses from SIRS and radio-sonde soundings that were nearly coincident in location and time. Differences in positions were limited to 2 degrees though the average distance apart was 1.5 degrees. Linear interpolation in time between radio-sonde observations at the encompassing synoptic times was used to estimate the radio-sonde thicknesses at the actual time of the SIRS observation, but if the radio-sonde observations were not both available then the time difference was limited to 2 hours. Due to the SIRS observations being confined to the sea areas while the radio-sondes are mainly released over land very few coincident soundings could be found. The ones that were finally used were all near the coast of the UK, the USA and Japan, and the weather ships and off-shore islands under the control of these countries. This selection of countries is fortuitous as they use different types of sondes (the British Kew MkIIb, the American Sangamo 1680 MHz, and the Japanese Code-

Sending Sonde), so that an attempt could be made to intercompare sondes using the SIRS soundings as a reference. The sonde observations that were used were those received by the Meteorological Office before any corrections had been made due to suspected consistent differences between the types of sondes. The comparison covered the periods October 01/22Z to 03/11Z (26 comparisons) and November 01/15Z to 05/21Z (34 comparisons), of 1973. During the earlier period VTPR instrument 1 on the NOAA 2 spacecraft was in use and during the latter period, instrument 2.

4) Results of the comparisons.

The standard deviation (s.d.) of the differences in thickness and their means (in the sense SIRS-sonde) were calculated for all the atmospheric layers from 1000-850mb to 1000-10mb for the three types of sondes separately and in combination, and for the two monthly samples. These, along with the number of comparisons in each sample, are given in Tables 1 and 2. The s.d.s. are plotted in figure 1 and the means in figure 2, as a function of the upper boundary of the layer, where the open and closed symbols represent results for October and November respectively.

Ignoring possible differences between the types of sondes it can be seen from figure 1 that there is an overall tendency for the s.d. of the thickness difference to increase with layer thickness, from about 2.5 gpdm for the 1000-850mb layer, to 8 gpdm for the 1000-100mb layer and 12 gpdm for the 1000-30mb layer. For comparison the s.d. of 100mb height measurements by the Kew Mark IIb sonde is reported to be 4.0 gpdm (ref.2) from which the s.d. of the difference in thickness between coincident sonde ascents would be $4.0 \times \sqrt{2} = 5.7$ gpdm. The s.d.s. appear to be greater during November than October for all thickness^{es} up to 1000-20mb as shown by the results for all sondes combined (dashed and continuous lines in figure 1) - this is especially noticeable for the layers from 1000-500mb to ¹⁰⁰⁰~~1000~~-150mb where, for each individual type of sonde, the s.d. is about 50% greater. For all layers up to 1000-250mb and for both months, the s.d.s. for the UK sondes appears to be smaller than those for either the US or Japanese sondes, but for thicker layers the US sonde has the smallest deviations. For layers from 1000-500mb to 1000-250mb, again for both months, the Japanese

sonde has the largest deviations.

The difference between the s.d.s. for the two months is accompanied by a corresponding contrast in the mean thickness difference as shown in figure 2. For layers up to 1000-250mb the mean difference for all sondes combined lies between -1.5 and +1.0 gpm. For thicker layers the difference becomes increasingly negative in October and positive in November, reaching -5 and +5 gpm respectively for the 1000-70mb layer. The thickness differences for the two months are significantly different at the 5% level of probability (using the "t" test) for all layers from 1000-200 to 1000-30mb. This difference in behaviour in October and November is likely to be associated with the change in VTPR instruments. The mean differences for the separate types of sondes are noticeably more scattered during October than November, but apart from the Japanese sondes which provide the extreme values of difference for layer up to 1000-300mb, there is no clear pattern of behaviour for different types of sonde.

In some ways figure 2 gives a misleading picture of the SIRS soundings although it may have some value to analysts having to draw charts plotted with a mixture of SIRS and radio-sonde observations. For instance the mean difference for the Japanese sondes during November look anomalous compared with other sondes. This really stems from a difference of about +2 gpm in the lowest layer but which appears for all layers up to 1000-300mb. The change in thickness difference across each layer gives a more realistic comparison of the relative temperatures implied by the SIRS and radio-sonde observations. In figure 3 is plotted the change in thickness across the layers between the standard upper-air reporting levels converted to the equivalent difference of temperature, for all sondes combined (ie. from the dashed and continuous lines in figure 2). From 700 to 400mb the SIRS mean temperatures for both months (and hence from both instruments) are in good agreement but are colder by about 0.5°K compared with radio-sondes. From 400 to 70mb the October SIRS soundings indicate lower mean temperatures by about 1°K , while the November SIRS soundings indicate higher mean temperatures, by about 1.5°K . The divergent temperature differences below 700mb emphasise the increased possibility of errors in SIRS soundings in the lower troposphere due to the effects of clouds, and uncertainties in the sea-surface temperatures.

With the small amount of data under consideration here it is not possible to explain unambiguously the various discrepancies between the SIRS and radio-sonde thicknesses previously described. The tendency for the SIRS thicknesses to be different from the sonde thicknesses probably arises from uncertainties in the weighting functions especially those which peak at the greater heights - this could be eliminated by making further comparisons to deduce more precisely the bias for each instrument. On the other hand the increase in scatter of the mean differences in thickness for the separate types of sonde (figure 2) and the increase in s.d.s. (figure 1) from October to November could be caused by an increase in atmospheric variability with approaching winter conditions (most of the comparisons were made at northerly mid-latitudes) giving rise to poorer forecast profiles and hence SIRS soundings.

5) Conclusions

From a comparison of seventy near-coincident SIRS and radio-sonde soundings during October and November 1973, the following conclusions are reached:-

- i) The mean differences between thicknesses measured by radio-sonde and the SIRS soundings are close to zero for atmospheric layers up to 1000-250mb. For thicker layers the SIRS soundings imply smaller thicknesses than sondes during October and greater thicknesses during November - for the 1000-70mb layer, the differences are -5 and +5 gpdm respectively. The difference between the October and November comparisons probably results from the difference between the two VTPRs on the NOAA 2 spacecraft, which were used during these periods.
- ii) No consistent difference in the thicknesses measured by British, American or Japanese sondes compared to SIRS as a reference could be detected.
- iii) The standard deviation of the difference in thickness from SIRS soundings and sonde ascents increases with layer thickness from 2.5 gpdm for the 1000-850mb layer to 12 gpdm for the 1000-30mb layer; the s.d. was greater in November than October especially for the layers from 1000-500mb to 1000-150mb.

iv) The results indicate that a continuous monitoring of the SIRS soundings is required in order that changes in their characteristics with season, latitude, synoptic situation (and with changes in the VTPR instruments) can be identified.

Acknowledgement.

I would like to acknowledge the assistance of T. Hull and Mrs M. Taylor for their assistance in the work.

References:-

- 1) McMillin, L. et al "Satellite infra-red soundings from NOAA Spacecraft".
NOAA Tech. Rept. NESS 65
(NOAA, Washington, Sept. 1973)
- 2) Harrison D.N. "The Errors of the Meteorological Office Radio-Sonde Mark IIb".
Met. Office - Scientific Paper No 15 (1962)

TABLE 1.

Means and standard deviations of thickness differences
(SIRS-SONDE), for October 1973 (Instrument 1).

Layer (levels in mb)	TYPE OF RADIO-SONDE											
	BRITISH			AMERICAN			JAPANESE			ALL		
	m	s	n	m	s	n	m	s	n	m	s	n
1000-850	-0.11	0.6	12	-0.06	1.1	8	-2.47	4.6	6	-0.67	2.5	26
1000-700	-0.34	1.0	12	-0.39	1.9	8	-1.03	5.7	6	-0.52	3.0	26
1000-500	-0.91	1.3	12	-1.71	3.3	8	-2.55	5.4	6	-1.54	3.4	26
1000-400	-0.99	1.9	12	-1.71	3.5	8	-2.72	5.3	6	-1.61	3.6	26
1000-300	-0.41	2.9	12	-1.04	4.2	8	-2.38	4.6	6	-1.06	3.8	26
1000-250	-0.16	3.1	12	-2.33	3.9	7	-1.21	4.1	6	-1.02	3.8	25
1000-200	+0.09	3.6	12	-2.90	4.6	7	-1.38	3.9	6	-1.21	4.2	25
1000-150	-0.33	4.0	12	-5.33	4.8	7	-3.55	3.7	6	-2.50	4.7	25
1000-100	-2.28	5.7	11	-4.68	4.2	6	-1.05	9.8	6	-2.59	7.0	23
1000-70	-5.37	6.8	11	-4.47	5.0	3	-4.83	6.4	4	-5.09	6.5	18
1000-50	-6.21	12.8	9	-4.13	4.8	3	+1.98	8.0	4	-3.78	9.0	16
1000-30	-1.96	13.2	5	-3.80	7.4	2	-2.58	9.0	4	-2.50	10.9	11
1000-20	-7.90	-	1	-	-	-	-9.70	1.6	2	-9.10	1.6	3
1000-10	-	-	-	-	-	-	-3.30	-	1	-3.30	-	1

Key:- m, mean difference of thickness (SIRS-SONDE)
in gpdm

s, standard deviation of differences in gpdm.

n, number in sample.

TABLE 2.

Means and standard deviations of thickness differences
(SIRS-SONDE), for November 1973 (Instrument 2).

Layer (levels in mb)	TYPE OF RADIO-SONDE											
	BRITISH			AMERICAN			JAPANESE			ALL		
	m	s	n	m	s	n	m	s	n	m	s	n
100-850	+0.31	1.2	19	+0.81	5.2	7	+1.64	2.3	8	+0.73	2.8	34
100-700	-0.12	2.2	19	+0.74	5.2	7	+1.95	4.4	8	+0.57	3.7	34
1000-500	-1.07	3.6	19	-0.41	5.4	7	+1.70	6.9	8	-0.28	5.1	34
1000-400	-2.18	4.5	19	-0.43	5.4	7	+2.20	7.7	8	-0.80	6.0	34
1000-300	-1.42	6.2	19	+0.07	7.4	7	+2.33	7.6	8	-0.23	7.0	34
1000-250	+0.45	6.8	19	+0.09	7.0	7	+2.33	7.0	8	+0.82	6.9	34
1000-200	+3.87	7.5	19	+0.37	6.5	7	+0.59	6.2	8	+2.52	7.2	34
1000-150	+6.33	7.3	19	-0.63	6.9	7	-0.30	6.3	8	+3.34	7.7	34
1000-100	+6.49	8.5	17	-0.83	6.0	6	+3.73	6.9	8	+4.36	8.2	31
1000-70	+5.07	8.3	15	+5.90	5.0	4	+5.45	11.5	8	+5.31	9.0	27
1000-50	+4.12	8.6	11	+8.90	5.5	4	+8.08	13.5	8	+6.33	10.4	23
1000-30	-0.38	9.6	10	+9.87	3.6	3	+13.58	14.0	8	+6.40	12.8	21
1000-20	-3.76	12.2	5	+11.4	4.3	2	+22.30	20.0	3	+7.10	18.2	10
1000-10	-1.80	-	1	-	-	-	+15.7	-	1	+6.95	8.8	2

Key as for Table 1.

UPPER-AIR LEVEL, MB.

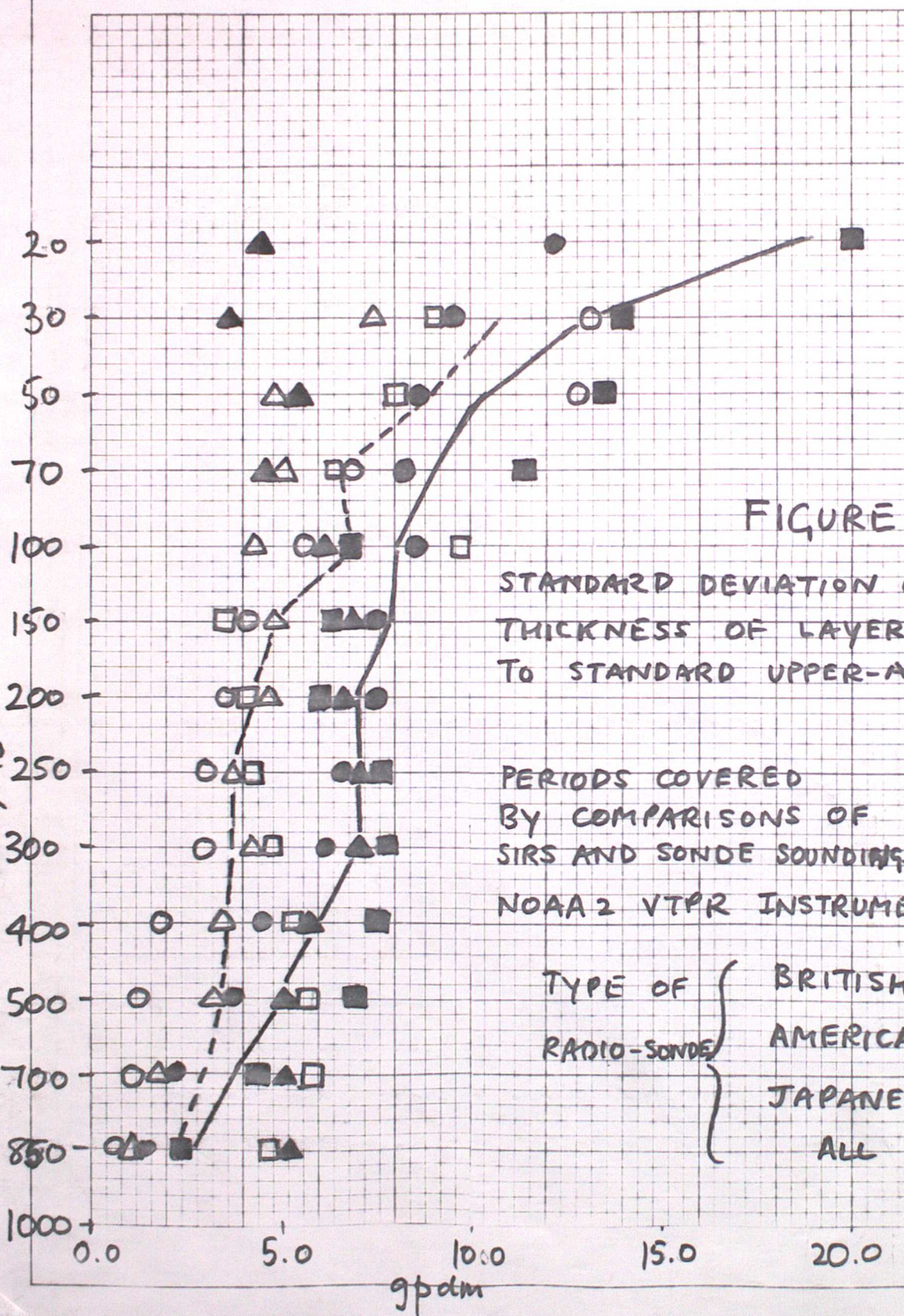


FIGURE 1

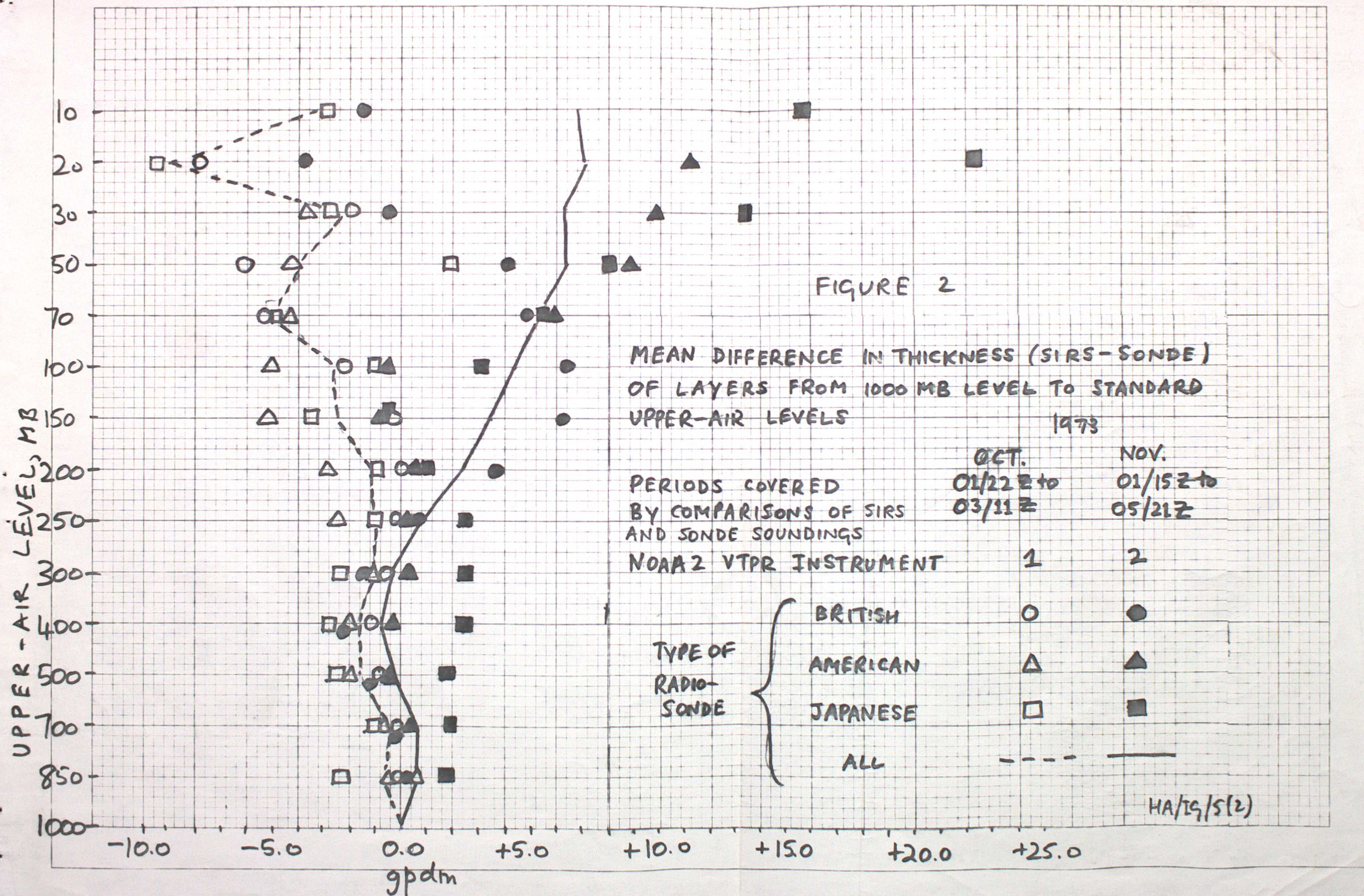
STANDARD DEVIATION OF DIFFERENCES IN THICKNESS OF LAYERS FROM 1000 MB LEVEL TO STANDARD UPPER-AIR LEVELS.

PERIODS COVERED BY COMPARISONS OF SIRS AND SONDE SOUNDINGS
NOAA 2 VTPR INSTRUMENT

TYPE OF RADIO-SONDE
BRITISH
AMERICAN
JAPANESE
ALL

1973	
OCT 01/22Z to 03/11Z	NOV 01/15Z to 05/21Z
1	2
0	●
△	▲
□	■
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UPPER-AIR LEVEL, MB

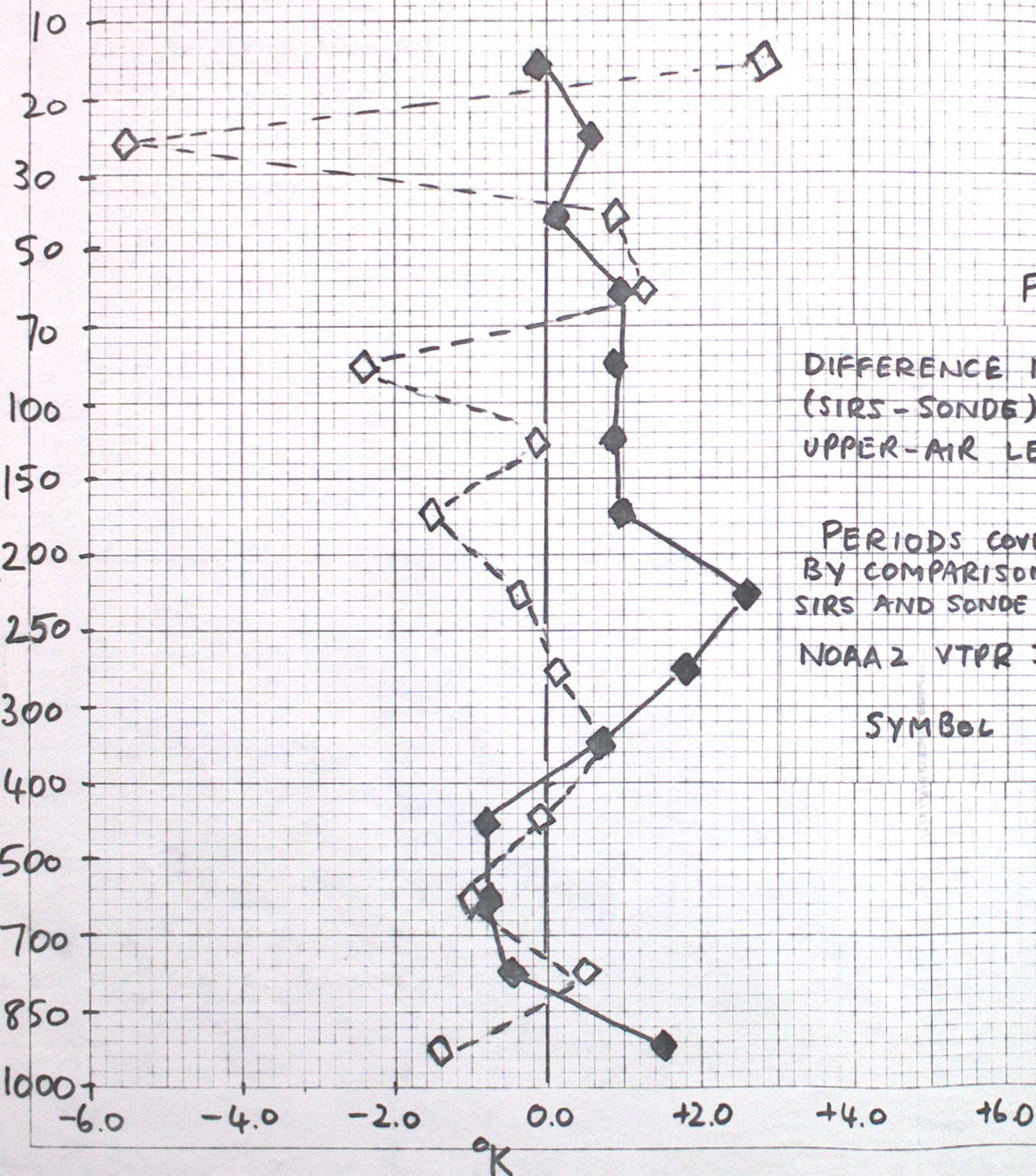


FIGURE 3

DIFFERENCE IN MEAN TEMPERATURE
(SIRS - SONDE) OF LAYERS BETWEEN STANDARD
UPPER-AIR LEVELS

1973

PERIODS COVERED
BY COMPARISONS OF
SIRS AND SONDE SOUNDINGS

OCT.
01/22Z to
03/11Z

NOV
01/15Z to
05/21Z

NOAA2 VTPR INSTR.

1

2

SYMBOL

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