MET 0 13 BRANCH MEMORANDUM NO 157

A COMPARISON OF BUCKET AND NON-BUCKET MEASUREMENTS OF SEA SURFACE TEMPERATURE

BY

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1. Procedure

Individual sea-surface temperature (SST) observations in the Marine Data Bank were used to create two separate data sets of monthly 5° x 5° area values for observations made using buckets and for observations made using other methods ("non-bucket"). The latter include observations made in the engine intake and by hull-sensors and by other methods, without distinguishing between them. The two data sets were created and quality-controlled by the methods and according to the criteria laid out in Met 0 13 Branch Memo No 137. The period covered by the data sets was 1960-1981, but the present comparison used only 1975-1981. because of uncertainties about the reliability of information on the instrumentation in the earlier years.

The analysis was carried out for each season (Dec-Feb, Mar-May, June-Aug, Sept-Nov) as follows, using the abovementioned monthly 5° x 5° area data sets.

i) For a given 5° x 5° area only individual months with data for both instrumental categories were included, to avoid sampling error. If the area had less than 8 such months out of the 21 possible in a given season (7 years x 3 months), it was not analysed for that season. Note however that individual monthly values could be based on single data.

ii) Mean difference μ (bucket minus non-bucket) was computed from the monthly values for each 5° square admitted by i)

iii) The standard deviation σ of the monthly values of (bucket minus non-bucket SST) was computed for each 5° square admitted by i).

(iv) The t-variate $t = \mu \div (\sigma/\sqrt{n})$ was computed where n was the number of months in the comparison ($8 \le n \le 21$). Note that this is a t-test comparing (μ,σ) with zero. A t-test comparing $(\mu_{bucket},\sigma_{bucket})$ with $(\mu_{non-bucket},\sigma_{non-bucket})$ could not be applied because the bucket data and the non-bucket data both contained substantial common meteorological variance, rendering t artificially small especially outside the tropics.

v) The t-variate with (n-1) degrees of freedom was used to estimate the significance of (μ,σ) in each 5° square admitted by i).

2. Results

Maps of mean difference μ (bucket minus non-bucket) are shown in Figures 1(a) to 1(d) and zonal means of μ are shown in Figure 2. The salient features are as follows.

R i) Buckets on average read nearly 0.1°C colder. Area-weighted averages are -0.11°C, -0.06°C, -0.08°C, -0.08°C for 60°N to 40°S for Dec-Feb, Mar-May, June-Aug, Sept-Nov respectively.

R ii) The relative coldness of bucket data is greatest in lower-midlatitude winter.

R iii) Buckets read warmer than non-buckets in upper-midlatitudes, particularly in summer but even in winter to some extent. This result is based on the Northern Hemisphere, there being few data south of 40°S

R iv) In the deep tropics buckets read on average about 0.05°C colder than non-buckets.

R v) Buckets tend to read warmer than non-buckets in the eastern half of the Pacific.

These results are confirmed by the maps of t-test significance shown in Figures 3(a) to 3(d).

3. Discussion

It can be assumed that the buckets used to measure SST in 1975-1981 were overwhelmingly of the insulated type. They could, however, still indicate lower SST than other methods because of

C i) evaporation from the top of the water sample, especially in cold, dry, windy weather.

C ii) limited loss of heat through the insulation as evaporation proceeds from the outside, especially if dewpoints are low and winds are strong.

C iii) limited loss of heat through the insulation if the air is colder than the sea, in particular if the wind is strong.

C iv) residual water, colder than the sea, in the bucket before immersion,

C v) the heating effect of the ship's engine etc. on non-bucket sensors.

The buckets could read higher than other methods if

W i) they had been left on a hot deck or in insolation

W ii) they contained residual water, warmer than the sea, before immersion.

W iii) the surface layers sampled were warmer than the deeper layers sampled by engine intakes or hull sensors.

Referring to the "Results" section

R ii) is explained adequately by the seasonal and geographical variations of C i) and C ii) and C iii).

R iii) can be explained by W i), W ii) and W iii) as regards summer warmth of bucket data. The persisting relative warmth of bucket data in winter reflects the behaviour of the data in the Gulf of Alaska and is discussed below.

R iv) is not a surprising result. It is known that tropical marine air temperature is generally a little lower than tropical SST, with relative humidity on average near 80%, so C ii) and C iii) can be expected to operate to a limited extent, along with C i).

R v) is the problem result. It may indicate that non-bucket sensors on large USA ships are at great depths, so that the water is colder, but this effect would be expected to he greater in summer (W iii)) which it is not (Figures 1(a) and 1(c)): note in particular the Gulf of Alaska. A further difficulty with ascribing R v) to a USA national practice is that there is no similar warmth of bucket data in the Caribbean, Gulf of Mexico or south western North Atlantic in summer (in winter such warmth would be cancelled by C i), C ii) and C iii)). Furthermore, examination of a few operational charts (for July 1984) revealed no marked tendency for a concentration of USA ships in the Eastern Pacific. Nor did it show a particular lack of eg USSR ships, another conceivable explanation for R v) if USSR ships' buckets had been less well insulated than those of other nations, causing (bucket minus non-bucket) to be relatively more negative in the regions traversed by USSR ships. Only a small sample of operational data was inspected in order to assess the potential for regional bias resulting from diverse national practices. A confident assessment would require analysis by nation of the observations in the Marine Data Bank.

The Gulf of Alaska did not suffer from data sparsity in 1975-81 and the results there in Figure 1 are spatially coherent.

National failure to report instrumentation type would tend to blur rather than enhance the apparent differences between buckets and non-buckets. National errors in use of the instrumentation code could produce regionally inverted differences, but if the USA or Canada had done this, the western North Atlantic would have been affected as well as the Gulf of Alaska; and if Japan or the USSR had done it, the western North Pacific would have been affected. Note that although around 70% of the data were, according to the instrumentation code, from buckets, only 30% to 35% of ships use buckets according to issues of WMO No. 47. Thus the present studies may indeed give too small differences between buckets and non-buckets, by a factor of about 2 on a global average, with regional fluctuations according to national practices.

A further hypothesis could have been that the night-time SST's were largely missing over the Eastern Pacific. This would, by making the comparison of bucket with non-bucket a daytime-only one, have enhanced the relative heating of buckets by solar radiation or hot decks (W i)) in summer. However a tally of the data for 55°-60°N 135°-160°W (for the year as a whole) for 1971-80 showed that 70% of the data were evenly distributed between 02, 08, 14 and 20 local time, with 25% well spread between 03, 09, 15 and 21 local time. This is to be expected, considering the universality of WMO observing practices. In any case, a lack of night-time data would not have explained the relative warmth of buckets at 50°-60°N in winter in the Gulf of Alaska, where insolation is feeble.

A final possibility is that the thermal structure of the Gulf of Alaska causes buckets to read relatively high temperatures, ie that the surface is warm relative to the underlying waters. This is considered unlikely in autumn and winter when the waters are well mixed and insolation is low. In spring and particularly in summer (Figure 1(c)) the hypothesis may be true more widely, as discussed above (R iii) and W iii)).

Figure 1a
BUCKET - NONBUCKET SST(HUNDREDTHS DEG C 1975 TO 1981)

WINTER(DJF)

COMPUTATION FOR EACH 5 DEG SQUARE MADE USING 8 OR MORE INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES

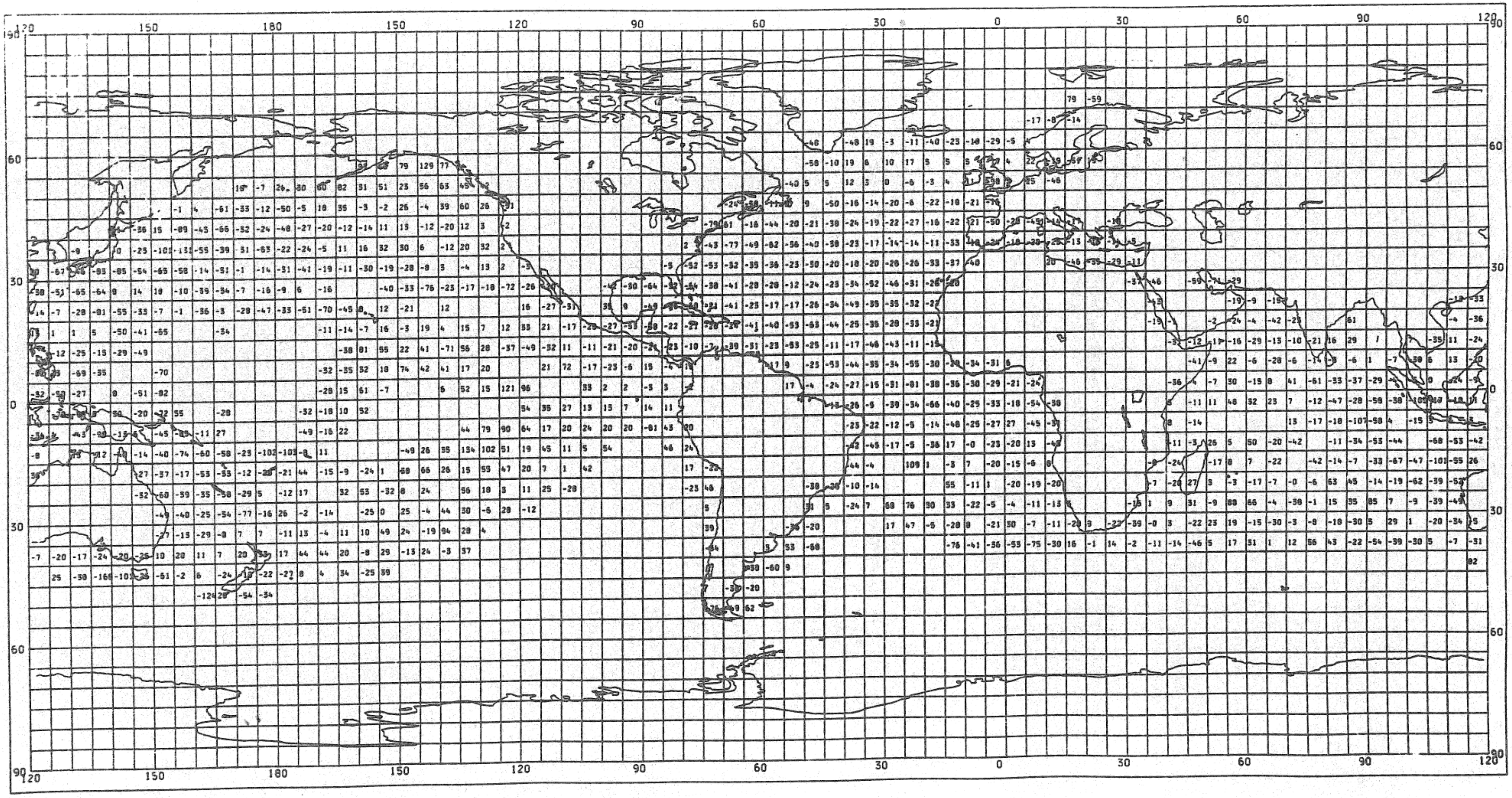

Figure 1b

BUCKET - NONBUCKET SST(HUNDREDTHS DEG C 1975 TO 1981)

SPRING(MAM)

COMPUTATION FOR EACH 5 DEG SQUARE MADE USING 8 OR MORE INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES

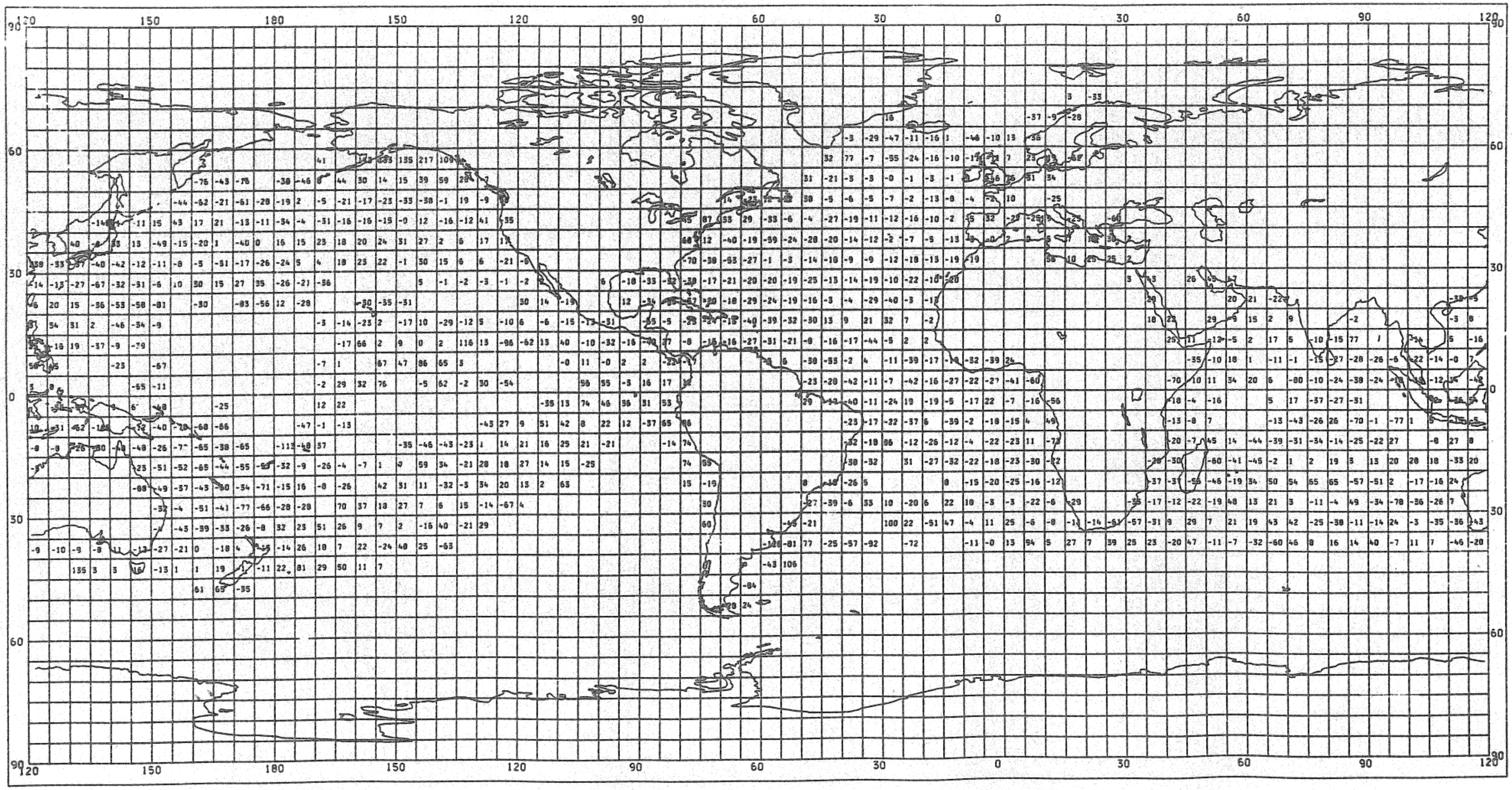

Figure 1c

BUCKET – NONBUCKET SST(HUNDREDTHS DEG C 1975 TO 1981)

SUMMER(JJA)

COMPUTATION FOR EACH 5 DEG SQUARE MADE USING 8 OR MORE INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES

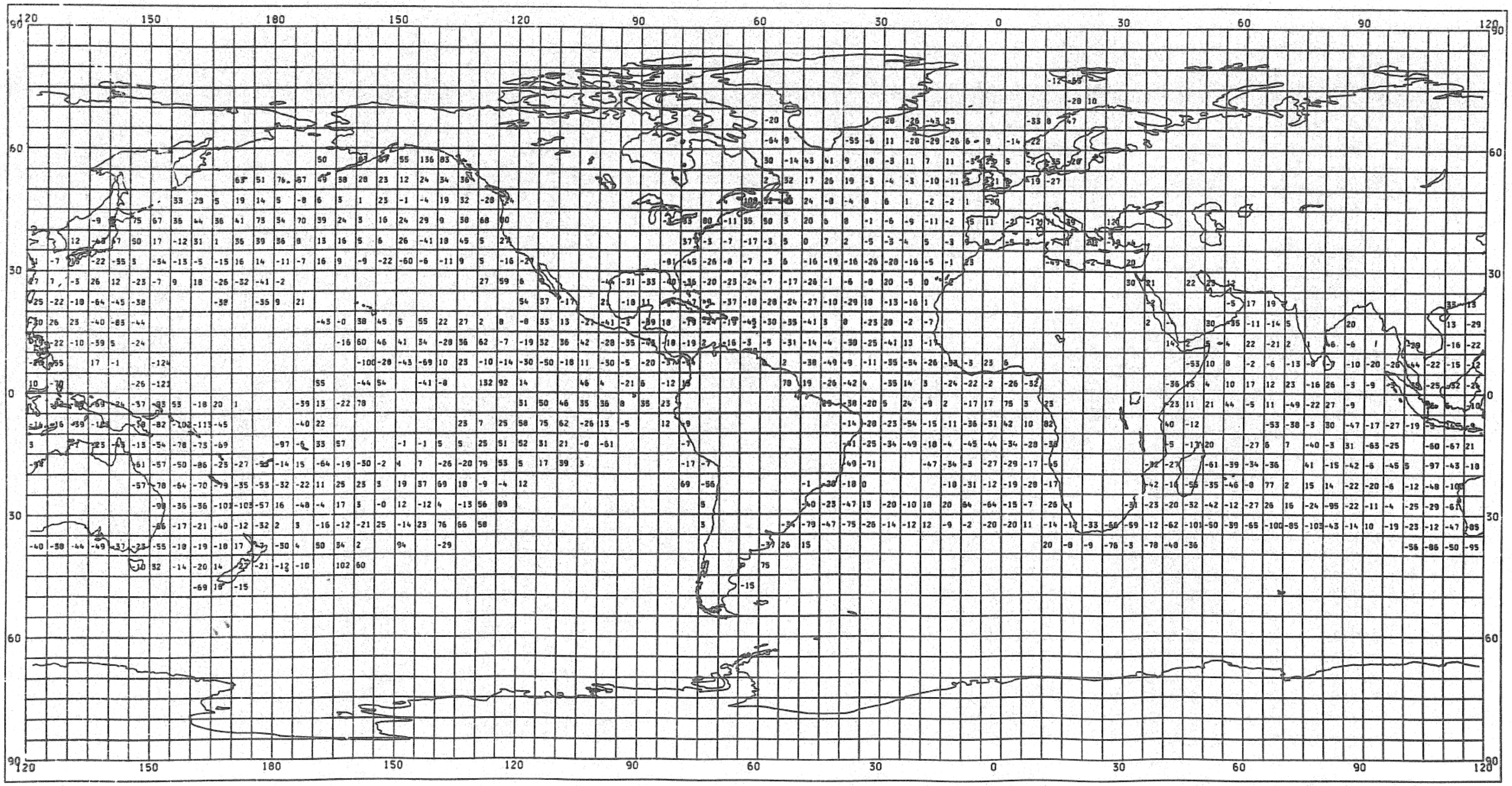

Figure 1d

BUCKET — NONBUCKET SST(HUNDREDTHS DEG C 1975 TO 1981)

AUTUMN(SON)

COMPUTATION FOR EACH 5 DEG SQUARE MADE USING 8 OR MORE INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES

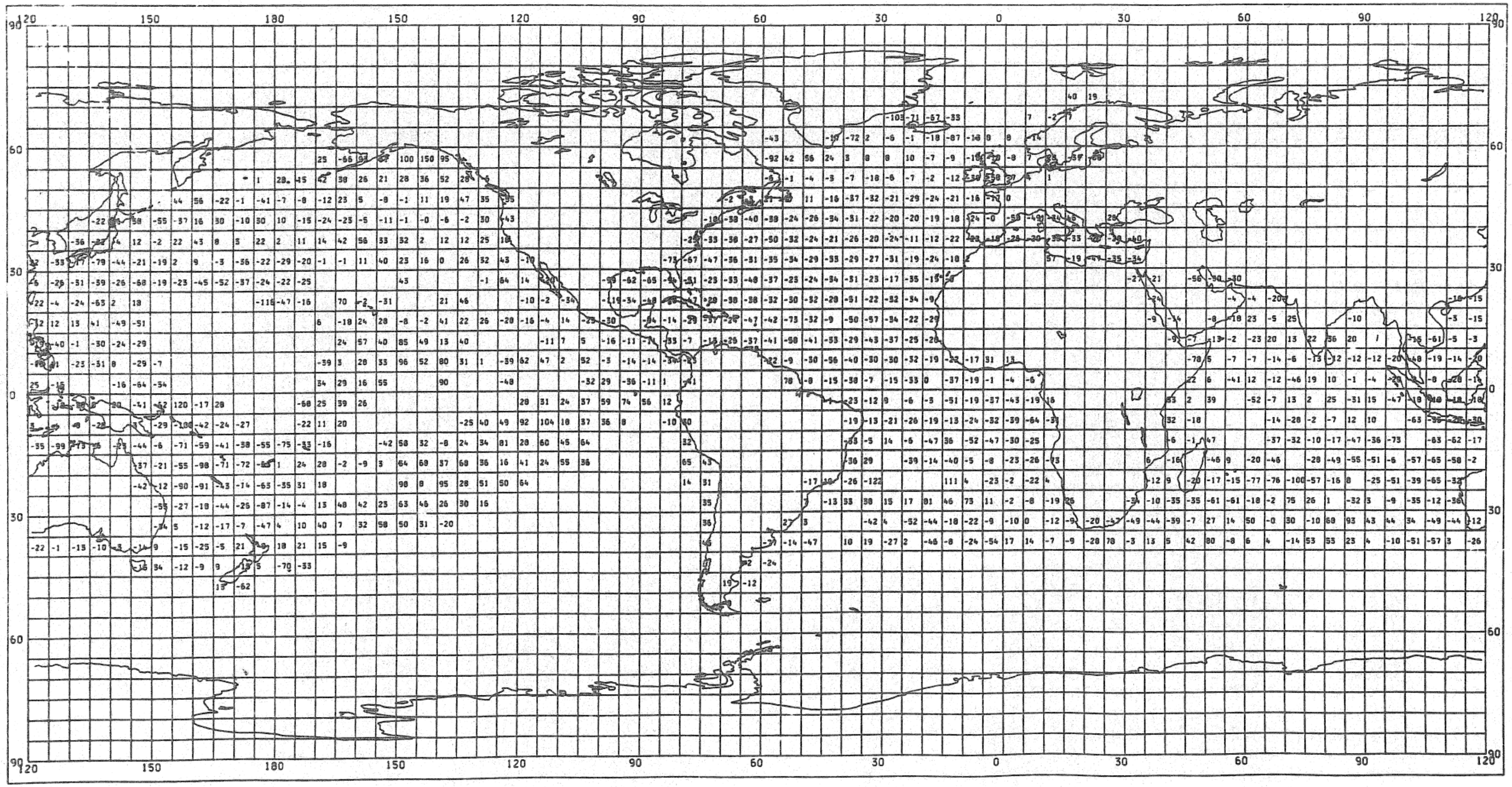

FIGURE 2. ZONAL AVERAGE BUCKET MINUS NON-BUCKET SST 1975–1981
5° SQUARE VALUES COMPUTED USING ≥ 8 INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES
ZONAL AVERAGE PLOTTED IF ≥ 50 % OF RELEVANT SQUARES HAVE COMPUTED VALUE
(BRACKETED POINTS = 40%–50%)

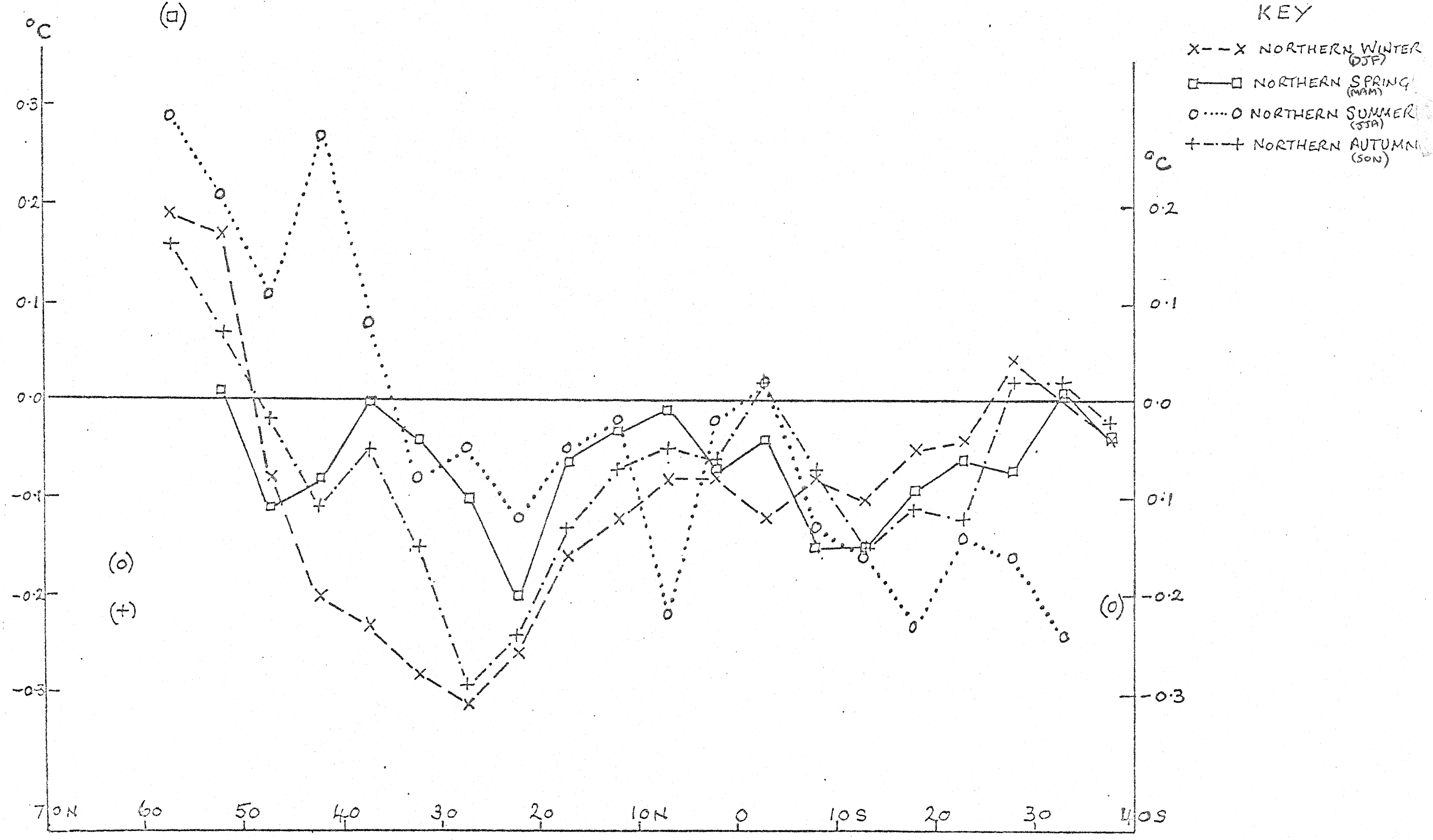

Figure 3a

T-TESTS 1975 TO 1981

WINTER(DJF)

COMPUTATION FOR EACH 5 DEG SQUARE MADE USING 8 OR MORE INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES

+(-)10(20)= BUCKET WARMER(COLDER) BY AN AMOUNT SIGNIFICANT AT 5%(1%) LEVEL

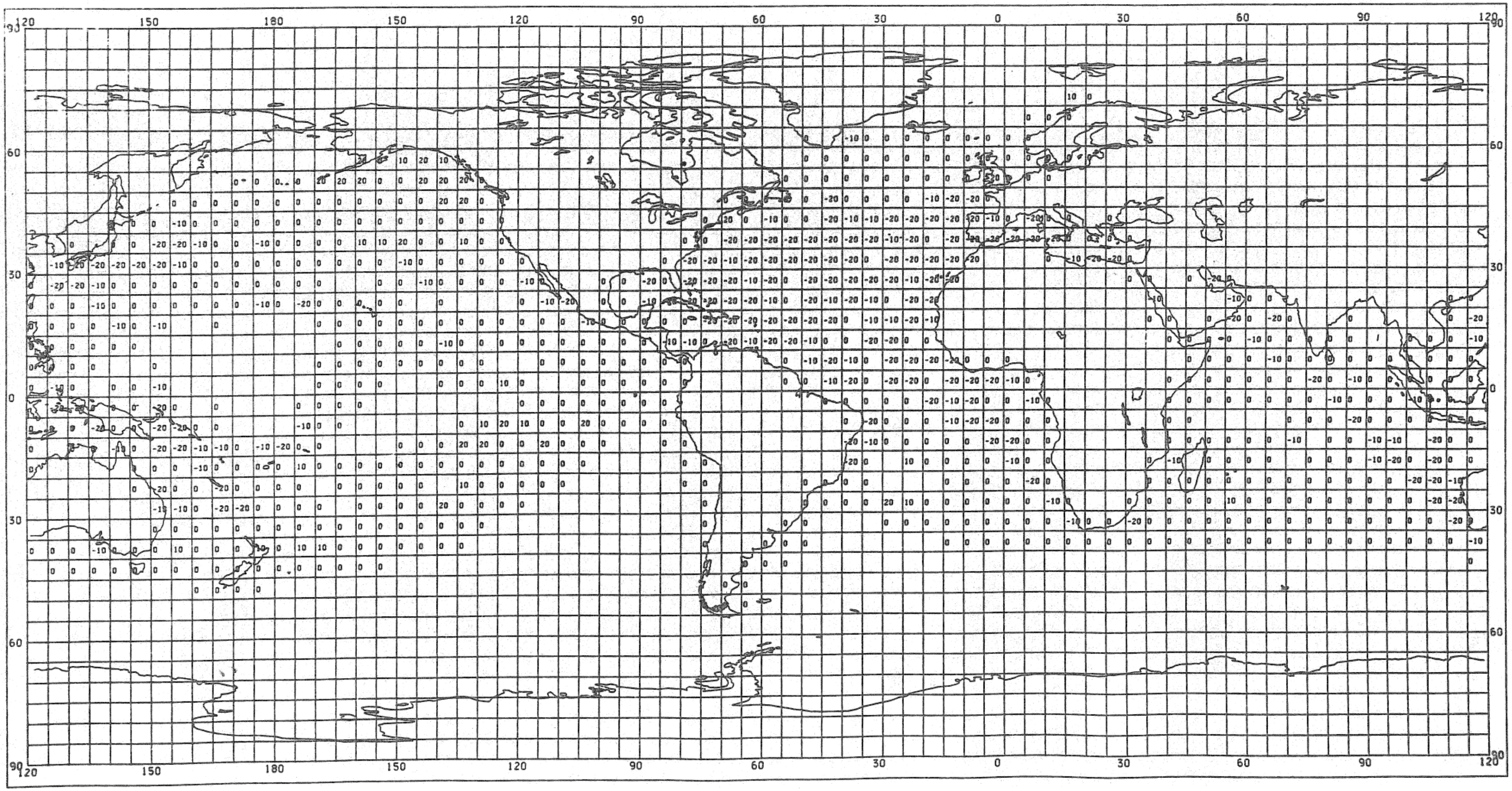

Figure 3b

T-TESTS 1975 TO 1981

SPRING(MAM)

COMPUTATION FOR EACH 5 DEG SQUARE MADE USING 8 OR MORE INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES

+(-)10(20)= BUCKET WARMER(COLDER) BY AN AMOUNT SIGNIFICANT AT 5%(1%) LEVEL

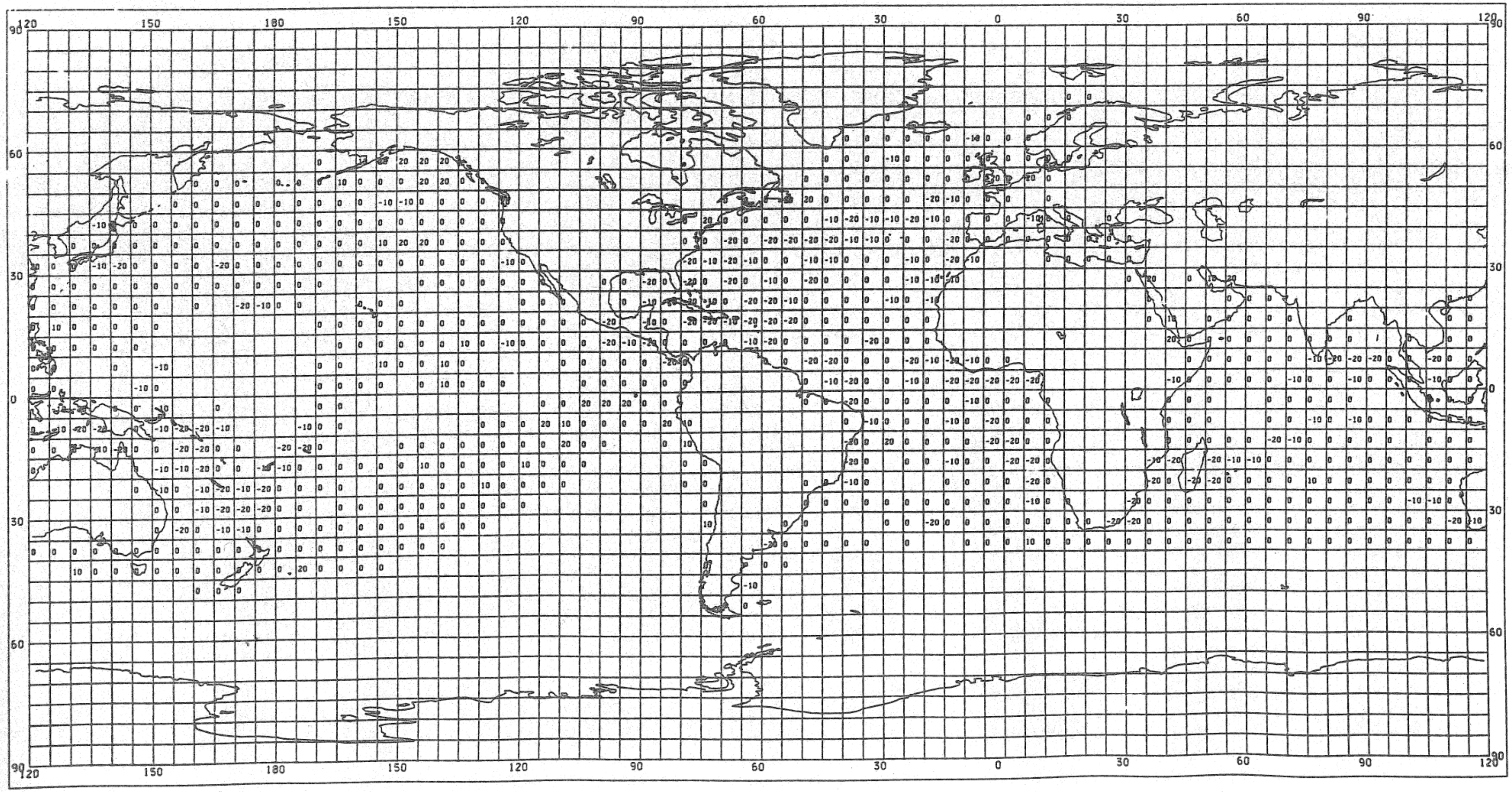

Figure 3c

T-TESTS 1975 TO 1981

SUMMER(JJA)

COMPUTATION FOR EACH 5 DEG SQUARE MADE USING 8 OR MORE INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES

+(-)10(20)= BUCKET WARMER(COLDER) BY AN AMOUNT SIGNIFICANT AT 5%(1%) LEVEL

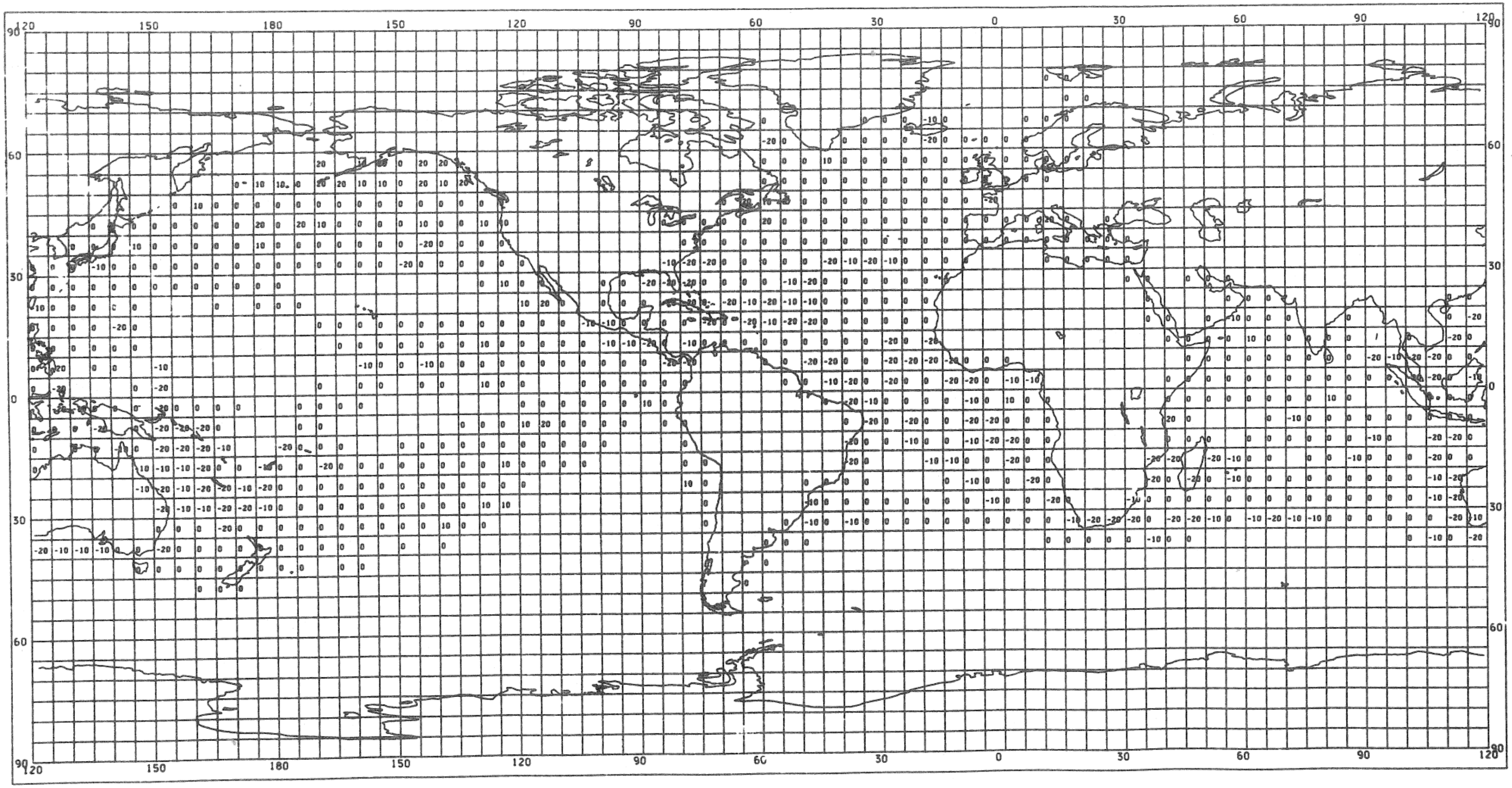

Figure 3d

T-TESTS 1975 TO 1981

AUTUMN(SON)

COMPUTATION FOR EACH 5 DEG SQUARE MADE USING 8 OR MORE INDIVIDUAL MONTHS WITH BOTH INSTRUMENTAL TYPES

+(-)10(20)= BUCKET WARMER(COLDER) BY AN AMOUNT SIGNIFICANT AT 5%(1%) LEVEL