NOAA Climate Database Modernization Program (CDMP)
Imaging Task, October 2004:

Document title:
Report of the Consultant on the Historical Sea-Surface Temperature Data Project

Reference information: Verploegh, G., 1966: Report of the Consultant on the Historical Sea Surface Temperature Data Project, 49 pp. plus Annexes.

Background: Imaged from a photocopy received from the Koninklijk Nederlands Meteorologisch Instituut [Royal Netherlands Meteorological Institute] (KNMI) in 2004. The report was prepared by G. Verploegh (consultant) and submitted to the third session (April 1966) of an Advisory Committee to the Executive Committee (EC) of the World Meteorological Organization (WMO). A report from the third session of the Advisory Committee, which discussed and made recommendations based on the consultant's report, was included in the final report of eighteenth session of EC (EC-XVIII) (June 1966) as Annex VI. However, it seems that the consultant's report submitted to the Advisory Committee was not archived by WMO (information from Teruko Manabe, WMO).

TO:

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Joe, 15 September 2004

Proposed for CDMP work, as time permits: Two miscellaneous items, which we have discussed and I finally got around to sending you:

1) Verploegh, 1966 report (HSST). Below is a "cover" page for the document, if you wish to add that to the front of the resultant PDF (edit as appropriate). (Note: "Executive Committee appears to be the proper terminology back in the 1960s. Apparently WMO converted over to "Executive Council" sometime afterwards.)

2) UK Series Manuals (CD-ROM). Mike Jackson scanned, and re-typed into MS Word documents, five Series Manuals, which document many of the historical data within the UK Marine Data Bank. Mike provided the digital versions of the Manuals via e-mail in 2001. The CD-ROM contains 10 directories with the following names:

series01-07scan	series08-10scan	series11-14scan	series15-15scan	series21-24scan
series01-07type	series08-10type	series11-14type	series15-15type	series21-24type

Within each directory is an html file, which puts all the relevant material into a webpage. The "scan" directories otherwise include only the gif images. The "type" directories include the MS Word file into which the Manual was typed by Mike, a gif image of the relevant punched card, and in some cases gif image(s) of Appendices. There was no card image for Series 15, and its directory contains two PDF files: one of the Manual, and the other of "contemporaneous Notes written by Brian Fullager when Series 15 card images were quality controlled and converted to MDB format."

With hindsight, I don't think the webpage approach was very useful. The documents (particularly the "scan" ones) are large and take a long time to load into a browser. Ideally, what might be most useful as a final product would be to have two PDFs for each Series: scan and type. Mike seems to have done an excellent job re-typing the Manuals into the Word documents (but I think it is important to have the scan versions, in case of typing errors).

However, the gif images don't appear to be ideal. Would we be better off re-scanning to tif images the photocopies of these documents (with color covers) received from the Met Office in 1995 (I still have those, if you do not)?

This isn't a particularly well-defined task yet, but I thought I would provide you with the current status and material so you can take a look and we can decide how to move forward, when resources become available. Thanks!

REPORT OF THE CONSULTANT
ON THE HISTORICAL SEA-SURFACE TEMPERATURE
DATA PROJECT

G. VERPLOEGH

Maart 1966

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W.M.O. Project on Historical Sea Surface Temperature Data

Report from Consultant to the Secretary-General of the World Meteorological Organization on the studies defined hereinafter:

(a) "To evaluate the task of analysing the sea surface temperature data kept by the United States and in particular to estimate possible means and costs of bringing up to date the analyses of sea surface temperature in squares for individual years and the cost of publication, taking into account that the ultimate aim is the production of a volume similar to "World Weather Records" giving historical sea surface temperature for each month for coastal stations and for the open oceans;

(b) To examine whether any work is in progress on this question in any other country;

(c) If time permits, to carry out the same studies as explained in paragraphs (a) and (b) above in respect to the following parameters:

- mean air temperatures
- mean humidities
- mean surface wind velocity and vector standard deviation of wind.

Following a decision of President W.M.O. the Consultant was requested to present his report in three parts:

1. on items (a) and (b) above;
2. on item (c);
3. on a combined analysis of the three items.

Paragraphs 1 to 7 of this report review general aspects of the HSSTD-Project as regards availability of data, statistical requirements for obtaining representative mean values, selection of suitable data, selection of the period over which the HSSTD-Project may be extended and selection of representative squares for which monthly averages can be prepared.

Paragraph 8 summarizes the conclusions made in the previous sections.

In paragraphs 9 to 11 procedures are indicated for the execution of the HSSTD-Project, as well as an estimate of the volume of work involved, in three parts as required.

1. Analysis of sea surface temperature data kept by the United States

1.1 List of decks

According to ADC-II/Doc. 16, Appendix E, the following punched marine data are preserved by the U.S.A. (as of March 23, 1962):

Period before 1940: decks 1-4   Period after 1944: decks 5-13

Deck*)	Data	Period of observation	Total volume
1	British Marine Obs.	1856–1953	3.835,963
2	Netherlands Marine Obs.	1854–1938	6,407,956
3	German Marine Obs.	1859–1939	6,104,576
4	U.S. Navy Monthly Aerol.Record	1920–1945	199,401
5	U.S. Merchant Marine Obs.	1949–1960	4,420,982
6	U.S. Navy Marine Obs.	1945–1951	597,537
7	U.S. Navy Marine Obs. (including Ocean Weather Stations)	1952–1961	2,135,138
8	Japanese Marine Obs.	1953–1960	721,755
9	Japanese Whaling Fleet Obs.	1946–1956	13,925
10	British Marine Obs.	1953–1956	527.286
11	U.S.S.R. Marine Syn.Obs. (I.G.Y.)	1957–1958	119,323
12	Netherlands Marine Obs.	1945–1955	275,839
13	German Marine Obs.	1949–1954	184,060
	Miscellaneous		
14	U.S. Navy Ships Logs Obs.	1942–1945	462,936
15	Japanese Marine Obs.	1937–1953	766,548
16	Danish Marine Obs.	1860–1956	29,673
17	Hollerith Surface Cards (Ocean Weather Stations)	?	67,924

*) Numbered 1 to 17 in this report for easy reference.

1.2 Further information on decks

1.2.1 The data which refer to the period before 1940 are given in the following units:

Deck	Ship position	air/sea temperature	wind direction	wind speed
1	1°, 5°, 10° sq.Marsden	$^{\circ}F$	32 points of compass	Beaufort
2	1°, 2°, 5°, 10° "	$0.1^{\circ}C$	16 " " "	"
3	1°, 10°	$0.1^{\circ}C$	16 " " "	"
4	station number	$^{\circ}F$	16 " " "	Knots

In deck 1 the wind direction was very rarely reported in the 16 "by" points (N by E, etc.).

Deck 4 refers to observations made at fixed marine stations in the Northern Hemisphere.

On the basis of a count of the number of observations which were erroneously indicated to fall in continental Marsden squares (ref. U.S. Inventory of marine surface decks, as of 3/23/62) the following probability percentages could be derived of an erroneous indication of the 10° Marsden square number on the punched cards:

deck 1:	0.6 per 10,000 cards
deck 2:	0.0 " " "
deck 3:	2.8 " " "
deck 4:	2.7 " " "

1.2.2 Regarding decks which cover the period from 1945 onwards the decks 8 and 11 do not contain data of the sea surface temperature itself; this temperature is indicated implicitly by means of the difference of air-sea surface temperature. The many errors which are made on board ship in coding this difference (ref. 6, 14) make these decks not suitable for their inclusion in the HSSTD-Project.

Deck 6 and the remainder of deck 7 contain observations mainly made in American home waters.

Deck 7 also contains observations made at fixed Ocean Weather Stations.

Deck 9 contains observations made in and near Antarctic Waters.

Deck 13 contains German observations north of 60 N. lat.

The decks 5, 10 and 12 contain observations generally made on merchant shipping lanes.

For the decks of this group the probability percentages of an erroneous indication of the 10° Marsden square number were obtained in a similar way as in para 1.2.1; the percentages are:

deck 5:	64.4 per 10,000 cards
deck 6:	1.5 " " "
deck 7:	2.0 " " "
deck 9:	analysing method not applicable
deck 10:	0.3 per 10,000 cards
deck 12:	0.7 " " "
deck 13:	0.0 " " "

Deck 5 needs a further explanation. All 61 continental Marsden squares from which a ship could possibly not report an observation , contain a varying number of observations from this deck. The frequency distribution is as follows:

no.of erroneous reports	no. of Marsden squ.containing erroneous reports	no.of erroneous reports	no. of Marsden squ.containing erroneous reports
0 - 9	21	80 - 89	1
10 - 19	11	90 - 99	1
20 - 29	5	100 - 109	1
30 - 39	1	110 - 119	1
40 - 49	3	120 - 129	1
50 - 59	5	200 - 209	1
60 - 69	2	210 - 219	1
70 - 79	4	220 - 229	1
		240 - 249	1

The total number of 2636 erroneous reports in 61 Marsden squares gives for this sample of 4,420,982 reports over 648 Marsden squares a probability frequency of 64,4 erroneous reports per 10,000 observations.The frequency distribution indicates a general source of error, which will be discussed in para 1.3.

The units used in decks 6 to 13 (except 8 and 11) are:

Deck	Ship position	air/sea temperature	wind direction	wind speed
5	$QL_aL_aL_aL_oL_oL_o$	^oF (sometimes ^oC)	dd-code	knots & Beaufort
6	$QL_aL_aL_oL_o$	^oF	16 points of compass	knots
7	$QL_aL_aL_oL_o$	^oF	dd-code	knots
9	$QL_aL_aL_aL_oL_oL_o$	^oF	dd-code	knots
10	1^o, 10^oMarsden squ.; L_aL_o	0.1^oF	32 points of compass	Beaufort
12	2^o, 5^o Marsden squ.; $QL_aL_aL_aL_oL_oL_o$	0.1^oC	dd-code	knots & Beaufort
13	1^o, 10^oMarsden squ.;	0.1^oC	dd-code	knots

1.2.3 In the group "Miscellaneous" the decks 14 and 15 were included which contain the only observations available over the period 1940-1945. Deck 16 was indicated as "Danish Marine Obs."; it contains in fact observations from expeditionary ships of various nationality (o.a. Dana-, Challenger-, Discovery-expedition). A large variety of units was used in this deck.

Deck 17 contains British observations from Ocean Weather Stations in the North Atlantic Ocean.

1.3 On the probability of errors in punched cards

When meteorological observations are punched two actions are done simultaneously; the series of figures is read and at the same time the fingers press the keyboard. Data on the number of errors made in punching cards are not known, but we can use the results of an investigation which relates to a similar action.

In transmitting a coded weather message the radio officer does in principle the same thing, the similarity is even greater with respect to the officer of a coastal radio station, who types the ships' weather message he receives, out on a teleprinter.

Verploegh (1965) has analysed the frequency of errors which are pertinent to telecommunicating weather messages from Netherlands selected ships to the Meteorological Institute at De Bilt. For this purpose he compared the radiogram which was handed to the radio officer on board ship with the telex message received at De Bilt. 5550 reports were scrutinized; it was found that each code figure was transmitted wrongly 9 times on an average. This results in an error probability of 0.16 per cent.

This probability figure is of course not directly comparable to the error probability of punching a code figure on a card; it gives however an indication of the order of magnitude to be expected. The punching of cards is normally being checked by means of second "check" punching; the same card is punched again and whereever a difference between the first and second punched hole occurs the error will be verified. On the basis of a comparison with the error probability in telecommunication we may expect that the chance that the same error is made twice in one code figure will be of the order of $(16.10^{-4})^2$ or 0.026 per 10,000. If we may apply these probability figures to the punching of the 3 code figures QL_aL_o or the 3 figures of a 10^o Marsden square, we arrive at the result that a first punching of QL_aL_o or the Marsden square may give rise to about 50 erroneous positions per 10,000 reports, which frequency will be reduced by check punching to about 0.1 erroneous positions per 10,000 reports.

Wrong entries in the log provide of course another source of error in ship positions. Synopticians are well aware of this kind of error, although the number of cases in which the ship position was reported and transmitted wrongly (and not the air pressure, another reason to suspect a ship position) appears to be rather small on itself (1.4 per cent). Ship officers normally copy the original log and forward the copy to the Meteorological Institute. As far as Netherlands ships are concerned it was found that these copies were already checked on board ship to meet the more strict requirements in climatology. Ship positions are for instance adjusted to what was found, after the observation was made, to be the true position of the ship; writing errors are at the same time corrected. In the sample of 5550 reports only 7 cases occurred in which an error in one of the code figures for ship position had been overlooked by the ship officer.

The customary practice of checking entries on the meteorological logbook on board ship comes of course forth from a long tradition; The Marine Observer (1964) described the same procedure for British vessels. It may be assumed that the same procedure is followed on board selected ships of all nations which have established an attentive maritime climatological service.

The discussion may make clear that a frequency of the order of 0.5 erroneous ship positions per 10,000 punched cards should constitute an acceptable norm; when a frequency of this order of magnitude is found, one may assume that the possible checks were made as regards making the entry in the log and punching the card.

The outstanding error frequency of deck 5 can in no other way be explained than by assuming that the original observations had only been punched once; both the order of magnitude of this frequency and the regular distribution over all continents seem to point this way. The conclusion is important with respect to the error frequency of sea surface temperatures in a given one degree Marsden square. The square being indicated with 5 code figures and the sea surface temperature with 3, it follows that for about 1 out of 60 cards on an average an erroneous temperature may be expected, either because of a wrong position or because of a wrong value for the temperature itself. This probability is a hundred or more times as large as could be derived in a similar way for other decks.

On a question from the Consultant over this deck the following answer was received from U.S.A. (letter from U.S.A. to Secretary-General of W.M.O., of February 1966).

"Remarks below concern Card Deck 116 - U.S. Merchant Marine.
1.1. Sea surface temperature was a separate entry on the observing forms; usually this was the water injection temperature. These values were not derived. Prior to the card punching, the forms were given a visual scan and obvious errors were eliminated; however, the punched cards received no editing. Since preparation of the inventory (3/23/62) the land locked observations have been removed".

Since the preparation of monthly means of the sea surface temperature for individual years requires the availability of uninterrupted long series of homogeneous and sufficiently checked data, it was felt on the basis of the results of the above analysis that also other data sources should be examined with a view to secure a satisfactory set of basic information.

2. <u>Availability of observations from long records.</u>

On the basis of information contained in ADC-II/Doc. 16 and on the basis of additional information received from the Fed. Rep. of Germany, the Netherlands, U.K. and U.S.A. the following inventory could be made of long series of historical sea surface temperature data (on punched cards) which are available in the countries of origin and in the U.S.A. and which would be suitable for the HSSTD-Project.

2.1 <u>British observations.</u>

In the United Kingdom the following decks of punched British Marine cards are available:

Series	Period	Total no. of cards
1	1854-1920	1,453,500
2	1921-1929	947,500
3,4	1930-1948	531,500
7	1945-1953	1,230,500
9	1953-1956(June)	480,500
13	1956(July)-1961	1,262,000

Not all observations from the period 1854-1920 are punched; the Mediterranean, the South Atlantic Ocean and the 10 degree squares alongside the Pacific coast of South America are not included in series 1. The punching of observations from this period is gradually being continued.

From the 4.2 million cards over the period 1854-1953 a number of 3.8 million cards were reproduced for U.S.A. (U.S.A. deck no.1 of para 1.1). Serie 9 was also reproduced for U.S.A. (U.S.A. deck no.10 of para 1.1).

A reproduction of the cards from the series 1 to 4 is also preserved in the Netherlands.

2.2 <u>Netherlands observations.</u>

The punching of marine data started in the Netherlands in the early twenties and has been kept up since. The deck of 6.4 million punched cards, covering the period 1854-1938, was reproduced for the benefit of U.S.A. in 1951 (U.S.A. deck no.2 para 1.1). A selection of cards from a later period (the North Atlantic Ocean was for instance not included) was reproduced in 1956 for the benefit of U.S.A. (U.S.A. deck no.12 of para 1.1).

In the Netherlands are also preserved about 5.5 million German observations from before 1940 (see para 2.3) and a deck comprising the series 1 to 4 of British observations. About 100,000 older Swedish observations, mainly from the period before 1920, are also kept by the Netherlands.

2.3 German observations.

The punching of marine observations started in 1941 with the most recent data, working backwards. In 1946 the available deck of cards was reproduced for the benefit of U.K., U.S.A. and the Netherlands; the 5.5 million observations mainly covered the period 1920-1939; earlier data are however also included. The copied data were not administrated. In 1956 about 0.6 million cards were reproduced for the benefit of U.S.A.; the cards refer to marine observations made at 12 a.m. in all oceans, except the North Atlantic Ocean, and cover the period 1906-1939. These two sets of data form together U.S.A. deck no.3 (para 1.1), in which a certain unknown number of observations may appear double because of the fact that the first set had not been administrated.

At present about 14.5 million marine observations covering the period 1889-1960 are preserved at the Seewetteramt in Hamburg. The systematic punching of earlier data continues.

Thus, about 8 to 9 million observations from German ships are available only at the Seewetteramt in Hamburg, in addition to the deck of about 5.5 million German data which is also preserved in other countries. The bulk of the additional data is confined to the Atlantic Ocean and adjacent seas.

2.4 American observations.

According to ADC-II/Doc.16 about 2 million observations from the beginning of the record to 1939 inclusive, are microfilmed. The punched data refer to later periods.

The distribution of data on microfilm was examined in the present study from copies of microfilmed tabulations of air and sea surface temperatures in five-degree squares in the Atlantic and Pacific Ocean and in individual months over the period 1885-1936. The copies were made available to the Consultant through the Secretariat. The data seem to refer mainly to the period 1920-1939, with very few observations appearing in individual months of earlier years. A tabulation of the total volume of data per ten-degree square is not available.

Since the U.S. data over later periods (1945-1960) are not directly comparable to the data mentioned above, because of a different method of observation (see 3.2), their space distribution is not included in this survey.

Chart 1 gives the space distribution per 10^{o} square over all oceans of German, Netherlands and British observations respectively for the period before 1940. The numbers of German data refer to the period 1906-1939.

Chart 2 gives the space distribution over the period 1945-1961 for British and Netherlands observations only. An estimate of the number of German punched data over this period is given for three 10^{o} degree squares.

A similar space distribution of observations from U.S. ships is not available for the period before 1940 (see 2.4).

3. Recommended selection of data for the HSSTD-Project.

3.1 Bucket temperatures.

In British, German and Netherlands ships the sea surface temperature is measured as a rule by means of a canvas bucket and a verified thermometer. At German vessels the canvas bucket was replaced from about 1950 by a specially designed bucket with an inserted thermometer (the "Marine Pütz").

Occasionally ships of these nations report nowadays the intake temperature; these reports are on German punched cards distinguished by means of an overpunch.

Information on the accuracy of the bucket and the intake method is given in W.M.O. Technical Note, No.2, Part I (W.M.O.- No. 26, TP.8, 1954). As regards bucket temperatures the standard error of routine measurements will of course be greater than the value of 0.2°C which results from carefully conducted comparative measurements. Bullig (1954) investigated a large sample of German observations taken during night and early morning hours in the tropics where the variability of the sea surface temperature is smallest. He concluded that the overall standard error of measurement should be 0.56°C or little less. He purposely left out the 12 hour and 16 hour (local time) observations, using only 4 out of the 6 observations made each day, since daylight conditions (insolation) were considered less favourable for an accurate measurement. (For this reason the daytime observations are also not included in the preparation of mean sea surface temperatures for individual months, which is being conducted at the Seewetteramt in Hamburg for a number of selected areas in the Atlantic Ocean (see ref. 4).

As far as the accuracy of <u>mean</u> data is concerned, a differentiation between nighttime and daytime observations does however not seem strictly necessary. In the Netherlands standard deviations of one observation with respect to the overall monthly mean sea surface temperature have been computed for areas in all oceans except the Pacific Ocean. In tropical areas the minimum values of the standard deviation are found to vary between 0.65°C and 0.70°C; the samples include all six day and nighttime observations from ships of various nationality (mostly Netherlands and German). It may readily be verified that 6 N observations having a "standard error" of 0.68°C give rise to the same value of the standard deviation of the mean temperature as 4 N observations do, which have a "standard error" of 0.56°C.

In temperate regions where the standard deviation of the sea surface temperature increases to about 2.2°C as a result of larger fluctuations, the measuring error has much less significance.

For the HSSTD-Project it does therefore not seem necessary to sort the observations out according to the hour of observation.

3.2 Intake temperatures.

The intake temperature shows a systematic mean difference with the bucket temperature; values of 0.2°C to 0.5°C are cited, the intake being higher. The spread of the differences is however stated to be considerable; the mean differences seem to persist also at the higher wind forces, including force 9. The features were shown to the author at the Seewetteramt from unpublished results; they are also mentioned in W.M.O. Technical Note No.2.

In American vessels the intake method is used since about 1946 (W.M.O., 1954). If these data were to be mixed with bucket temperatures, they should firstly be reduced to "bucket values". The reduction factor depends on a large variety of factors, both instrumental and physical, and may at certain places of the ocean with an abnormal thermal stratification of the upper water layers (for instance regions of upwelling deep water, or at sharp surface boundaries of currents) amount to 1°C or more. An example of such large differences was for instance found from series of comparative measurements taken by Dutch ships near Cape Guardafui in the Indian Ocean (unpublished).

Since real climatological temperature changes are of the same order of magnitude (ref. 2, 11) the HSSTD-Project would greatly be complicated if intake and bucket temperature were both included. If the data were mixed without applying a (variable) reduction factor, one might note a "climatological" change of, in fact, instrumental origin in any area where the composition of the respective data gradually or abruptly changes with time (for instance in the North Atlantic before and after World War II with respect to the marine data kept in the U.S.A.).

It is therefore recommended to use only bucket temperatures for the Project.

3.3 Selected period before 1940.

For this period only observations from British, German and Netherlands ships are available on punched cards (together with a number of Swedish observations which are preserved by the Netherlands). The sea surface temperature observations all refer to bucket temperatures; because uniform instruments and buckets were used, there is no reason to expect a systematic difference between data from ships of different nationality. The validity of the assumption can easily be verified on the basis of a comparison between one degree square means which are published in the respective recent German and Netherlands climatological atlasses for the Mediterranean (ref. 9, 10).

The number of observations which were received annually since 1880 is for these three nations well represented by the graph shown in figure 1, which refers to German observations only and which had kindly been put to the disposal of the Consultant. The observations from before 1903 mainly originate from sailing vessels. The space distribution of these earlier data differs from those made in later periods. This feature is well illustrated by the table of Annex 1, which gives the number of Netherlands, German and British observations, preserved in the Netherlands, in certain selected 10 degree squares in the Indian Ocean and the Mediterranean. In Marsden squares 434 and 475 for instance, Netherlands shipping ceased to occur after the sailing era, while German and British steam ships kept on entering these squares quite regularly, i.e. as far as the month of January is concerned. In the years of World War I German observations fail altogether, while there is still a substantial number of Netherlands and British observations available (except in 1918).

The Table shows that the total number of available data in a given area does not necessarily provide information on the data distribution for individual years. The Table also shows that one must use data of various nationality in order to ensure the widest possible coverage in individual years.

In principle all years from 1860 to 1939 inclusive may be included in the HSSTD-Project, not only as regards data from areas at frequented shipping lanes, but also as regards other (larger) areas outside these lanes. It is not possible to select in this period the year before which monthly sea surface temperature means would generally loose their significance. In the series of monthly means of each selected area there will be gaps because of lack of data in a particular month; the gaps will however occur in different calendar months and in different years for the different areas over the ocean.

The selection of the size of the areas outside the main shipping lanes will therefore also depend on the distribution of data over the individual years. One cannot, so to speak, put all available data into a computer and just turn the wheel. A careful assessment of the efficiency (or representative value) of each selected area should form part of the execution of the Project.

3.4 Selected period after 1945.

In this period the Project runs parallel with another international scheme. According to Res. 35 (Cg-IV) monthly climatological summaries will be prepared of a.o. the sea surface temperature for a number of selected areas over all oceans. It is intended to extend these summaries back to the year 1950. The data used for this scheme have a different composition due to differences in observation methods and techniques. For example some ships use the bucket method, others the intake method, while in addition more ships are gradually being fitted with a fixed resistance thermometer.

The monthly mean temperatures which result from this Scheme may show systematic differences in certain areas as compared to the sample of bucket temperatures, which is used for the HSSTD-Project. To permit a true comparison between monthly temperature means from prewar years and those from postwar years, the HSSTD-Project should overlap the Scheme of Res. 35 (Cg-IV) over at least 10 years, e.g. over the period 1951-1960. One may thus be able to establish reduction factors for the overlapping years.

It is therefore recommended to extend the HSSTD-Project at least over the years 1947-1960, using the same sample of bucket temperatures from British, Japanese, German and Netherlands ships. Whether 1947 or a later year should be taken as the beginning of this period will depend on the number of available data and will have to be decided by the centre carrying out the computation for each area selected.

4. Selection of representative areas.

4.1 Spatial distribution of observations.

From about 1900 the number of observations from steamvessels began to increase strongly, while at the same time the number of observations from sailing ships decreased. Since about that time the observations are concentrated on the various main steamship routes, which are often constituted by great circle or rhumbline tracks between harbours. Chart 3 gives an impression of the density distribution of older data (before 1940) per 2 degree square in the various oceans. An important seasonal shift, relating both to steam ship and sailing ship data, may be noted over some parts of the ocean.

The density distribution is not much changed in present times; this may be inferred from Chart 4 which was prepared by W.M.O. to indicate the "sparse areas" as regards reception of synoptic marine data.

In selecting areas for which mean data are to be prepared, due account should be given to the sometimes large gradients in the spatial distribution of observations. One should aim at selecting areas with an uniform spatial distribution, so that more or less equal weight will be given to the various conditions which may prevail in the area. This is especially important in the case of a large temperature gradient existing in the area.

4.2 Time distribution of observations.

The number of "selected ships" that pass through a given area depend amongst others on the sailing schedule of these ships. From the present synoptic weather charts one may already infer that it may take days, even at a frequented shipping lane, before another ship traverses a given one degree square. At less frequented lanes the time interval may be weeks or even months, since the actual route which a vessel takes depends on a number if factors including the prevailing weather conditions and also for instance the threat of a tropical cyclone.

A characteristic example of the time distribution of ship observations in a given area is shown in Annex 2 (reproduced from reference 12). The example indicates that the observations from an individual month in an individual year mostly originate from few ships and are therefore concentrated around a small number of days of the month. It is only at the few highly frequented shipping lanes that the distribution over the days of an individual month will be more uniform.

Increasing the size of a selected area may in principle lead to a better spread of the observations over the days of the individual month and thus to a more general representation in the sample of conditions which occurred in the area during the particular month. Extending the area in the direction of the main shipping lane does however not help much, because in including more observations from the same ships one would not obtain a more regular spread of the data over the days of the month. One could better have the area extended over other shipping lanes, whereever this would be possible in view of other requirements.

4.3 <u>The required minimum number of observations per month.</u>

In the similar German national project of monthly sea surface temperature means for selected areas in the Atlantic Ocean (ref. 4) a number of 15 observations per month was accepted as a minimum. With this number the standard deviation of the mean temperature itself would be 0.15°C or smaller, if a standard "measuring error" of 0.56°C is assumed. The latter "standard error", which was derived from a sample of observations in a tropical area, is not purely a "measuring error", since it also includes deviations, however small, which result from true fluctuations of the sea surface temperature itself.

The problem of setting a minimum to the number of observations to be included per month becomes more complicated when not only areas of a very small size, but also larger "sparse" areas, are to be considered. The following approach is taken.

When it is our purpose to study the reality of a climatic sea surface temperature change of for instance 0.5°C between two individual months, the corresponding monthly means should have a standard deviation $\sigma_m \leqslant 0.12°C$ in order to be normally sure that the indicated change is real[1]. We may wish to apply this investigation to conditions found at a certain position ("station") in the ocean; the spot values of mean temperatures can be approximated by selecting the smallest area possible (1° square); over such area the mean temperature gradient can normally be neglected.

1) See page 14.

If we do not have a sufficient number of observations in the square to meet the required accuracy of mean temperatures, we have to extend our analysis over a larger area. In order to rule out the effect of a mean temperature gradient on the standard deviation of the mean temperatures, we select a number of 1° squares, more or less evenly distributed over the entire area, and compare the two monthly sets of local temperature means. If, for instance, we would have taken ten such squares, we could have allowed $\sigma_m \leqslant 0.36°C$ for each of the local temperature means to bring out a real average change of 0.5°C over the entire area.

The density of data is generally so small over the oceans, except in certain narrow lanes, that it is of no use to think generally in terms of one- or two-degree squares. Over large parts of the ocean the study must be based on five- or ten-degree square temperature means so that only large scale temperature changes can be investigated. From a number of studies (ref. 2, 11) it is known that such changes have an order of magnitude of 0.1° - 0.5°C in the tropics and subtropics and 0.5° - 2.0°C in temperate regions. In the first two zones the standard deviation of the sea surface temperature varies from 0.7°C to about 1.2°C, increasing further to about 2.2°C in the temperate zones of the ocean.

The largest scale in which we are interested comprises a mean temperature change over an area of about the size of half an ocean in one of the hemispheres. For an analysis on this scale the following requirements seem to be necessary:

(1) a minimum of 20 observations per square;

(2) the mean temperature gradient $\Delta \bar{T}$ should be less than 5°C over the entire selected square.

With these requirements the upper limit for σ_m (standard deviation of the mean temperature in a square) will vary from 0.17°C to 0.35°C in the tropics and subtropics and from 0.35°C to 0.60°C in temperate regions. When mean data of a number of 10 to 20 selected squares in an area are considered, which fulfill these minimum requirements, it should generally be possible to investigate the existence of climatic temperature changes as an average over large ocean areas. Where more observations are available, smaller scale details can be investigated.

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1) In climatology one will often have to be contented with statements based on less rigid statistics. A difference between two average values is, for instance, often already considered "significant", when it exceeds twice the value of the standard deviation; in the present example $\sigma_m \leqslant 0.12°C$ would then suffice to bring out a "real" climatic change of 0.25°C.

The restriction of $\Delta \bar{T} \leqslant 5^{\circ}C$ over a selected area means that we cannot always select ten-degree Marsden squares. Where $\Delta \bar{T} \leqslant 2.0^{\circ}C$ per degree latitude we should select a five-degree square or a zonal arrangement of such squares, for instance a ($5^{\circ} \times 10^{\circ}$) square, being the upper half or lower half of a ten-degree square.

4.4 Selection on the basis of the available number of observations.

At data centres the marine punched cards are stored in boxes per ten-degree square and per calendar month. If it can be indicated beforehand that a given ten-degree square does not contain a sufficient number of observations from a certain deck to have a selection made per individual year, much work could be saved.

On the basis of the foregoing reasoning, the minimum number of observations per month, per year, which a ten-degree square should contain is taken to be 20, or 40 when the square has to be divided into two parts because of a too large mean temperature gradient.

Over the (rounded number of) 80 years before 1940 we require therefore a minimum number of 20 x 12 x 80 = 19,200 observations per ten-degree square. Over some parts of the temperate zones of the ocean the minimum number should be about 38,000. Chart 1 gives the following information.

Atlantic Ocean and adjacent seas: the available number of observations is generally sufficient between 60° N and 40° S with the exception of a few squares in the South Atlantic.

Indian Ocean and Chinese Sea, up to 120° E: North of the equator the available number of observations is generally sufficient; South of the equator the number is just about sufficient in some ten-degree squares and insufficient in other squares.

Pacific Ocean: the available number of observations is generally insufficient; apart from certain ten-degree squares near the continental coasts the number of observations is far too small to permit the preparation of meaningful ten-degree square temperature means for individual months.

For the period 1945-1960 the same conclusions hold true, as may already be inferred from Chart 2, which indicates the available number of British and Netherlands observations respectively.

4.5 A first selection of representative areas (see Chart 5).

Up till now the discussion was concentrated on the statistical properties of the available material. Bearing these in mind, we may now proceed to select the areas in such a way that, whereever possible, local features of the physical properties of the oceanic conditions can be investigated.

One of the interesting features is for instance the cooling of the sea surface as the result of upwelling of deep water. One may wish to investigate the variation from year to year of the intensity of the cooling and the extension of the source. One should then select a grid or network of 1° or 2° squares, as the number of observations permit. Some wellknown regions where upwelling takes place can be investigated this way, i.e. off the African westcoast near Cape Verde Islands, the upwelling off Aden, the situation near Cape Guardafui. The intensive upwelling off Ras Haifun can however not be studied in such detail because of the smaller density of observations.

Another interesting problem concerns the question whether a local temperature change might be due to a cooling of the local watermass or to a shift of the prevailing ocean current. The problem is for instance pertinent to the situation off the eastcoast of North America north of Cape Hatteras; the shift of el Niño is, of course, a very wellknown example.

It is not the object of this study to investigate all these phenomena in detail. This should be part of the Project itself. It is also not possible to perform these studies at this stage. One should know the time distribution of the local data, i.e. the variation of the number of observations from year to year in each of the areas concerned, in order to select an adequate coverage of representative areas. All that can be done at the moment is to indicate where a finer resolution of areas to be selected should be tried out.

As regards the open ocean two alternatives may be considered.

(a) The selection of a restricted number of areas, which are distributed over the ocean at certain "strategic" positions with respect to the main systems of surface currents, for instance a series of squares in the axis of a current and some squares to fill the gaps between currents. This method corresponds with the scheme for Marine Climatological Summaries according to Res. 35 (Cg-IV).

It is however difficult to apply this method as a general scheme because of the general scarcity of the available data. The statistical features of the time and spatial distribution of the observations often determine the location and the size of the area to be selected. Moreover, in a discussion of the results of the similar German project for the Atlantic Ocean the need was felt for a more even distribution of selected areas over an ocean with a view to verify the question to what extent certain features which are discovered have a local origin. Finally, in many individual years the numbers of observations will be just sufficient to meet minimum requirements; in these cases we need a rather dense coverage of selected areas to permit the verification of the representativity of local temperature differences.

(b) In each ten-degree square which contains a sufficient number of observations, one or more areas are selected. We thus get a more or less regular distribution of areas ("stations") all over the ocean. This solution permits within the limits set by the statistics of the available data the discovery and the subsequent investigation of features of various scale. It constitutes an objective scanning of the ocean surface by means of a grid which is independent of the surface phenomena themselves and which can be given a finer resolution where a closer survey of local phenomena is desirable and, of course, possible.

In selecting areas a compromise has been sought between the two alternatives. Although the first method is cost-saving, it might prove to be more costly in the end, when interesting features are discovered which call for a closer investigation and thus for a renewed processing of data in selected areas which had been omitted at first. Especially since the data which result from the Project are used for deductive studies, we may certainly expect this to happen.

As a compromise it is therefore suggested to apply method (b) to ocean regions outside the main shipping lanes, except in the Pacific where only method (a) can be applied, and to select a restricted number of (small) areas at the lanes where many observations are available. As has been mentioned before, it should be left to the climatologist (or body of experts) who will be in charge of the evaluation of the Project to decide, on the basis of the exact number of observations, on the coverage of smaller selected areas in ocean regions where a finer resolution would be desirable (for instance over the Gulf Stream or in regions where upwelling occurs).

The areas which have been selected are shown in Chart 5. The detailed selection was made on the basis of information contained in the working sheets of the Netherlands Climatological Atlasses for the various oceans (a new atlas for the Atlantic Ocean is in preparation for some time). The number of observations per 2° square and per 5° square, which were entered on these working sheets and which referred to decks of punched cards kept in the Netherlands, were modified with the help of the information described in para 2 of this report.

The areas which have been selected by the nine Responsible Members for the preparation of Marine Climatological Summaries according to Res. 35 (Cg-IV) will eventually also have to be taken into account.

4.6 Selection in Pacific Ocean.

The general scarcity of punched data from the Pacific Ocean renders the selection of representative squares to a difficult problem. The available volume of data could perhaps be supplemented with U.S. marine observations on microfilm, which could be processed by means of FOSDIC (film optical sensing device for input to computers). The U.S. data mainly refer to the period 1920-1939 and can be used, since in U.S. ships the bucket method was used in this period for measuring the sea surface temperature.

It should be noted that Japan has prepared for the period from 1942 to 1960 monthly 2 by 5 degree square surface temperature means over the entire area of the North Pacific up to 52° N (see para 5, vi). This example could be followed by preparing similar monthly averages for earlier period and for the squares where data are available. Another alternative would be to prepare seasonal averages of the sea surface temperature for individual years. Much depends, however, on the possibility to use the U.S. marine observations on microfilm.

Since there are several alternatives to be considered and not all information, necessary to make a definite proposal, is available during the course of the present study, it is recommended that the problem is continued to be studied by the data centre which will be given the task to carry out the HSSTD-Project for this ocean.

In order to arrive at an estimate of the costs involved in carrying out the HSSTD-Project for this ocean, a number of squares were selected. The squares which are indicated on Chart 5 have been selected on the basis of the available number of data (mostly from British ships) on punched cards. The ten-degree squares which are left blank contain very few observations, so that even a combination of these squares would not yield sufficient data to compute significant monthly or even seasonal means for individual years.

5. Other publications of sea surface temperature means for individual months.

In the above selection of representative areas due consideration was given to other publications of sea surface temperature means for individual months. The various publications are listed hereafter. As regards the Atlantic Ocean profitable use may be made of the experiences gained in study (v); moreover, by supplementing the HSSTD-Project to the monthly mean data which resulted from this study, an important reduction of the work to be done may be obtained.

As regards the Pacific Ocean the HSSTD-Project may supplement the mean data published in (i), (iii) and (vi).

(i) Imperial Kobe Marine Observatory, Japan.

The mean atmospheric Pressure, Cloudiness, Air Temperature and Sea Surface Temperature of the North Pacific Ocean and the Neighbouring Seas.

Annual publication of monthly 1 degree square means in the South China Sea, Yellow and East China Sea, Sea of Japan and neighbouring waters of the pacific side of Japan. Period 1911-1941 (see Chart 6).

The number of observations are not published.

(ii) "Réseau Mondial", published by the Meteorological Office in London. Period 1911-1934.

For two five-degree squares in the Atlantic Ocean (see Chart 7) monthly and yearly data of

- mean latitude and longitude of the observations
- mean pressure at Mean Sea Level

- mean air temperature
- mean sea surface temperature.

For the last three elements the departures from normal and the number of observations are given.

The computation of the data took place at the Netherlands Meteorological Office.

(iii) "Monthly Meteorological Data for ten-degree squares in the Oceans", published at first by the Netherlands Meteorological Office (publ. no. 107 b) and later by the "Secretariat du Comité Météorologique International".

Six-monthly publication over the period 1917-1930. For several ten-degree squares in the Atlantic, Indian and Pacific Ocean (see Chart 7) monthly means of

- scalar wind force
- vector wind
- sea-level pressure
- air temperature
- sea surface temperature
- cloudiness.

Also: the percentage of hydrometeors and the number of observations.

The computation of the data from American, Australian, British, Danish, German and Netherlands ships took place at the Netherlands Meteorological Office, which office also took care of the publication.

(iv) Five-degree square means of individual months of all oceans between 65° N and 60° S, used in preparation of the U.S.A. "Atlas of Climatic Charts of the Oceans" by Willard F. McDonald. Period 1885-1936.

The following information was given by the Permanent Representative of U.S.A., in his letter of February 1966 to the Secretary-General of W.M.O.

"The card decks used in preparing the Atlas of Climatic Charts of the Ocean have been destroyed and are not listed in the inventory of marine surface decks. The data which are available on microfilm contain monthly means of air and sea surface temperature with the corresponding numbers of observations. The mean latitude and mean longitude of the observations in a square were not computed. Print-outs from the cards used in preparing the Atlas are no longer available."

From this information it may be concluded that the data are based on observations from (presumably) U.S. ships and not from for instance European vessels, since the decks of the latter observations are listed in the U.S. inventory of marine surface decks.

A copy of some of the microfilmed data which are mentioned in the above letter, was also sent to the Secretary-General. From a study of these copies it was found that the data formed an uninterrupted series over the period 1920-1936; before 1920 very few data are present.

(v) Atlas der Monatswerte von Wassertemperatur, Wind und Bewölkerung auf dem Seeweg Europa-Südamerika. Deutscher Wetterdienst, Seewetteramt, Einzelveröffentlichungen Nr.5, 1954 (bearbeitet von Dr. H.J. Bullig).

In this atlas mean sea surface temperatures are given for individual months, for the years 1906-1913, 1922-1938 and for a number of 14 test areas on the shipping lane Europe-South America. Anomalies are also given.

This comprehensive work is at present being continued for years prior to 1906 and after 1938. Also other test areas will be included. Chart 8 shows the position of test areas used in this publication and also of test areas which are planned for further research.

(vi) Marine Climatological Tables of the North Pacific Ocean, 1942-1960. Japan Meteorological Agency, Techn. Report No. 17; Part 1, 1962; Part 2, 1963.

Monthly 2 by 5 degree square means over the area within 0° - 52°N and 110° E - 110° W, with the numbers of observations for each square, for the period from 1942 to 1960 inclusive. Elements are: sea surface temperature, air temperature, wind speed, air pressure, dew-point temperature and wave height.

The Tables were computed from observations from Japanese ships. In many squares, no observations were available.

An inventory of the current monthly sea surface temperature charts which are nowadays regularly being published by various institutes for sea areas in the Atlantic and Pacific Ocean, is being made by the ACMRR "Working Party on Fishermen's Charts" of FAO. WMO is represented in this Working Party by the author of this report. The inventory is expected to be completed within a few months.

6. The background of special computational procedures.

6.1 Introduction

Many of the monthly means will be based on a relatively small number of observations. One may expect therefore sometimes large differences between the averages from consecutive months. To enable an assessment of the reality of such differences and to detect errors one should know the standard deviation of the mean and also, one should be aware of meteorological factors which influence the element concerned. It may for instance occur that the observations in one month were predominantly made at conditions of strong winds, while in another month light winds prevailed. Would the mean sea surface temperature be affected by this change of environmental conditions ? One should be aware of the order of magnitude of the effect, if existent. This means that it may be necessary to consider perhaps also other elements during the processing of data, although they are not required for publication.

This problem and the practical problem of the conversion of units (degree Fahrenheit into degree Celsius and Beaufort number of the wind into meters per second) will be investigated here in some detail.

6.2 Assessment of the representativity of temperature means.

When the standard deviation is computed from the small number of observations of an individual month, the relative error will generally become too large for practical purposes. A more accurate estimate of this standard deviation may be obtained by taking the variance which is computed from the large sample of observations over all years and subtract from it the mean squared deviation of the means of individual months with respect to the overall mean temperature. One thus obtains an average variance for all individual months concerned.

Overall standard deviations of the sea surface temperature and the air temperature have been published in the Netherlands climatological atlasses. They have been recently also been computed for the Atlantic Ocean, per two-degree square and for all months. The values were as a rule corrected for a mean gradient over the area from which tha sample was taken. It may therefore not seem necessary to compute standard deviations of the sea surface temperature as part of the execution of the HSSTD-Project. For the purpose of assessing the mean accuracy of the computed monthly mean temperatures, it generally suffices to compute in the way indicated above and for a few representative test areas (to be judged from the existing marine climatological atlasses), the mean variance of observations in an individual month.

The mean sea surface temperature and the mean air temperature show a rather strong correlation with the wind speed. Verploegh (1960) analysed the effect on the basis of a large sample of data from the Indian Ocean; he found that an increase of the wind force by one step of the Beaufort scale is accompanied by a decrease of both the air and sea temperature of 0.17°C on an average. This holds true for the investigated range of wind forces from 2 to 7 Beaufort. It was tentatively concluded from this result "that the primary cause of the variation of temperature with wind force lies, to a large extent at least, in the wind stirring the sea, since otherwise the sea temperature would show smaller variations than the air temperature."

Bullig (1950) analysed the effect in a different way. He correlated monthly sea temperature anomalies to anomalies of cloudiness and mean wind speed of the corresponding months. The regression was found to be

$$A_{Tw} = -0.18\, A_N - 0.37\, A_{\bar{v}} \quad ; \qquad R_{1,2,3} = 0.56$$

The weight of the wind speed appears to be twice as large as the weight of the cloudiness.

Precipitation is often accompanied by heavy cloudiness; it is interesting therefore to recall some studies of the effect of precipitation on mean temperatures. Keyser (1939) analysed the effect on the basis of observations in the Chinese Sea. Verploegh (1960) distinguished between observations made in dry weather, in "bad weather" conditions (rain occurred during the four hours preceding the time of observation) and in rainy weather (continuous rain during the preceding four hours). A sample of observations in the Bay of Bengal (Marsden square 028, month November) showed for instance a reduction of the mean air temperature of 2.1°C and of the mean sea temperature of 0.5°C in rain with respect to dry weather conditions. A more general discussion showed that, as far as the monsoonal and equatorial sea areas in the Indian Ocean and Chinese Sea are concerned, the mean temperature reductions can be related to the precipitation frequency (f_p) as follows:

$$(\Delta T)_{air} = -0.04 f_p \qquad (f_p \text{ in per cent})$$

$$(\Delta T)_{sea} = -0.01 f_p$$

The influence seems to be much stronger on the air temperature, with the effect that for instance mean summer temperatures of the air over the Bay of Bengal and the Arabian Sea are 0.5°C higher in dry weather than in "bad weather" conditions.

While a knowledge of the standard deviation of the monthly temperatures helps in detecting obvious discrepancies, a further understanding of the origin of discrepancies and the subsequent weeding out of doubtful data is arrived at by considering individual temperatures or individual temperature means in combination with the corresponding data on wind, cloudiness and precipitation when observed. This procedure is normally used at the preparation of marine climatological atlasses. It is one of the reasons why for instance in the Netherlands the preparation of an atlas is started with the preparation of monthly frequency distributions of temperatures, pressure, wind, etc. in all areas of the ocean concerned. The German project of the preparation of climatological means for individual months in a number of test areas in the Atlantic Ocean includes a careful study of each individual observation as regards sea and air temperature, wind and cloudiness.

It would certainly have advantages, if the HSSTD-Project could make use of data which had already been scrutinised in this way, having been used for the preparation of a national climatological atlas. The fact, however, that the material will be broken down into many small samples of data from individual months means that there will remain the need of studying the sea surface temperature means in combination with, in any case, corresponding means of the air temperature and of the scalar wind speed. Even if the latter values were not to be published, they should be included in the processing of data because of the more strict requirements for weeding out doubtful data in small samples.

6.3 Conversion of units.

Temperatures

Because the conversion of degrees Fahrenheit into degrees Celsius is linear, observations which were read in degrees Fahrenheit can be tabulated first and the sum of the readings, or the mean temperature, can afterwards be converted into degrees Celsius.

Wind speed

Wind speeds were observed and recorded in units of the Beaufort wind scale. Mean wind speeds are, however, required in meters per second.

The conversion from Beaufort steps into m/s is not a linear one; the scale which is recommended by CMM-IV (Rec. 5) for the conversion of marine observations is reproduced in the following table at page 24.

The non-linearity of the scale would require the conversion of each observation before tabulating and, as regards the computation of the mean vector wind, before the observed wind velocity is decomposed into its north and east component. This procedure is time-consuming or, when for this purpose a computer with a largercapacity is used than otherwise would be required, it might prove to be too costly.

If, on the other hand, the conversion of mean wind speeds can be approximated with sufficient accuracy by means of a linear regression, the problem would certainly be simplified. The fact that the non-linearity of the scale is restricted to its lower and upper end, i.e. to wind forces which have comparatively a small frequency, may prove to constitute a favourable condition.

The position of the regression line will be investigated hereafter on the basis of three types of wind frequency distributions, which cover together a wide range of wind conditions found over the oceans:

a) generally light winds, storm frequency less than 0.5%;
b) generally moderate winds, storm frequency about 5%, and
c) generally moderate to strong winds, storm frequency about 10%.

The frequency distributions which are given below were derived from existing climatological tables.

Beaufort	equiv. speed	wind frequency distributions (in per cent)		
	m/s	(a)	(b)	(c)
0	0.8	1	0.2	0.1
1	2.0	15	5	4
2	3.6	31	14	10
3	5.6	27	24.7	18
4	7.9	15	20	22
5	10.2	7	14	17
6	12.6	2.5	10	11.2
7	15.1	1	7	7.5
8	17.8	0.5	3.6	4.7
9	20.8	-	1	3.1
10	24.2		0.5	1.8
11	28.0		0.02	0.55
12	(32.0)		0.002	0.05

mean wind force ($\bar{B}$)	2.79	4.00	4.62	Bft
mean wind speed ($\bar{v}$)	5.39	8.12	9.47	m/s
standard deviation of mean speed	0.29	0.42	0.48	m/s

These three pairs of means fit a linear regression of the form (see figure 2).

$$\bar{v} = 2.23\ \bar{B} - 0.81 \qquad (\pm\ 0.02)\ \text{m/s}$$

Since the deviations from the linear relation between mean wind force and mean wind speed are one order of magnitude smaller than the standard deviation of the mean speed itself, the relation may be considered sufficiently accurate.

Note

Since the Beaufort wind force is indicated on the international maritime meteorological punch-card, if the wind force has been estimated according to the Beaufort Scale (Tech. Reg. App. F, Part A, p. 73) and since all maritime meteorological punch-cards for data prior to 1949 contain the Beaufort wind force (except measured wind data), the above mentioned procedure can be applied to all decks which are recommended for the HSSTD-Project.

The same procedure can be applied with respect to the present international equivalency-scale (W.M.O. Code 1100); the regression is:

$$\bar{v}' = 2.54\ \bar{B} - 2.77 \qquad (\pm\ 0.06)\ \text{m/s}$$

Finally $\bar{v}'$ (Code 1100) can be converted into $\bar{v}$ (CMM-IV, Rec.5) by means of the relation:

$$\bar{v} = 0.88\ \bar{v}' + 1.62 \qquad m/s$$

Thus, observations of estimated wind speeds, which have been converted by means of Code 1100 before punching (since 1949 when Code 1100 came into force) do not need to be repunched for climatological processing, even if the Beaufort wind force itself was not punched.

7. Availability of representative data on parameters added to the HSSTD-Project (concerns item c of Consultant's task).

7.1 Air temperature

The air temperature was measured as a rule on board ship together with the sea surface temperature. The numbers of the respective observations are almost equal. It is recommended to process this element together with the sea surface temperature to enable an assessment of the representativity of the latter, irrespective of any decision regarding the publication of mean air temperatures.

7.2 Humidity

The following information can be given for the decks of data prior to 1949 when a new code form was introduced.

British punched cards:	very few relative humidity observations punched, only in series 1 (1854-1920) and 4 (1933-1939), in a few squares .
Netherlands punched cards:	no relative humidities punched.
German punched cards:	very few relative humidities punched.

Data from 1949 to 1960:
Relative humidities are only punched in German cards. There is furthermore a large diversity in parameters; wet bulb temperature, dew point and specific humidity.

It seems that humidity cannot be included in the Project as far as the years before 1949 are concerned. For later years a study should be made of the means and costs to obtain a uniform humidity parameter. It seems that the water vapour pressure would be an important parameter for the Project.

7.3 Scalar wind speed

Sea surface temperature observations are as a rule accompanied by observations of the wind speed and direction. Because of the need of including the scalar mean wind speed in the study of temperature means for individual months (see 6.2), and because the scalar mean wind speed may be used in an alternative method of deriving the vector standard deviation of the wind (see 7.5), it is recommended to add the scalar wind speed as a parameter to the HSSTD-Project.

7.4 Surface wind velocity

Because the accuracy of a mean wind velocity depends on the variability of two parameters - the scalar wind speed and the wind direction - the computation of mean wind velocities might not yield sufficiently representative values when based on relatively few observations (20-40) from the larger 5 x 10 degree or 10 x 10 degree squares. In fact, as regards the larger squares in which a certain gradual shift of the mean wind direction exists, one should perform a similar statistical study on the required minimum number of observations in a square and the size and location of representative squares to be selected, as was done in this report with respect to the sea surface temperature. In certain ocean regions a different selection of squares may be found necessary.

The statistical problem is of less importance with respect to small selected areas (two-degree squares for instance). Therefore, if it is decided to add the surface wind velocity as a parameter to the HSSTD-Project, it is recommended to compute this data only for selected areas having a size smaller than 5 x 5 degrees. If, on the other hand, a wide coverage of mean wind velocities over the oceans is required, a statistical and climatological study on the selection of the larger representative areas should be made first.

7.5 Vector standard deviation of the wind

The idea of including the vector standard deviation of the wind in marine climatological summaries has for the first time been discussed at the session of the CMM Working Group on Maritime Climatology in 1959 in De Bilt. It was then proposed to abandon the widely used parameter of the constancy of the wind and to represent the wind rose distribution by means of the normal statistical parameters of a distribution, i.e. the first and second moments or, in this case, the mean vector wind and the vector standard deviation. An alternative proposal was to represent the wind rose by means of elliptical percentile curves indicating the probability of an individual wind vector falling inside the area enclosed by the curve. In Res. 35 (Cg-IV) the vector standard deviation was adopted.

From the older working documents on the subject and from recent discussions which the Consultant had with some members of the aforementioned CMM Working Group it appears that there is still some doubt on the usefulness of the vector standard deviation when applied to surface wind distributions. Many of these distributions, and especially those in temperate and equatorial regions, are not elliptical, but show a double structure as if two (or perhaps more) elliptical distributions are superimposed. It was also argued that the trade wind rose shows an important excess over a normal elliptical distribution. In all these cases the vector standard deviation would not suffice to indicate the true probability distribution of the wind vectors and could therefore also not be used to check the significance of mean vector wind differences in the usual way (see also Crutcher (1957), who made similar remarks in a study on the standard vector-deviation wind rose).

It was however thought that the data for the future marine climatological summaries would provide a good opportunity to study the problem in all its aspects. In view of the present discussion it is important to note that in formulating the proposal for the future computation of a vector standard deviation one had in mind small selected areas which would normally contain many observations.

The inclusion of the vector standard deviation of the wind in the HSSTD-Project presents the following difficulties:

a) in most cases (individual months) few observations (20-40) are available from relatively large areas, which would result in a large standard error of the computed standard vector deviation;

b) as the computation involves taking the square of wind speeds, a computer with a larger capacity than required for the other parameters will be needed; the combination of data from the original decks will also become more complicated and more costly.

As regards the second argument an alternative solution may be indicated. Brooks, Durst and Carruthers (1946) have indicated an approximate method to derive the vector standard deviation from the scalar mean wind speed and the mean vector wind, when these values are known. They prepared a simple graph, which is reproduced in this report (Annex 3). The derivation is based on the assumption of a normal elliptical wind distribution. If for each individual month the mean scalar and the mean vector wind were given, any research worker may easily find corresponding values for the vector standard deviation for those months and those areas in which he is interested.

In summarizing the discussion it is recommended that the problem of the statistical usefullness of the vector standard deviation of the wind be studied in detail before a decision is made regarding its inclusion in the HSSTD-Project

8. Summary of conclusions from previous paragraphs

8.1 Basic data on sea surface temperature

8.1.1 The long series of observations over the period 1854-1939 all refer to bucket temperatures. The strict requirement of homogeneity of the series implies that intake temperatures, which appear in some decks of observations made after 1945 and which show a systematic difference with bucket temperatures, cannot be used, since the systematic differences are as large as the climatic sea temperature variations to be studied (see para 3.1 and 3.2). It is therefore recommended to use only bucket temperature observations for the HSSTD-Project.

8.1.2 It will not be necessary to sort the observations out according to the hour of observation (see para 3.1).

8.1.3 The following Table contains an estimate of the volume of data on punched cards, which can efficiently be used for the HSSTD-Project. The various sources are mentioned in chapters 1 and 2.

Deck	Period	Volumes ($x 10^6$) preserved by U.S.A.	Netherlands	F.R. of Germany	U.K.
British Marine Obs.	1856-1948	2.6	~~2.6~~ 1.7	-	2.9
German " "	1859-1939	5.8[1]	5.5	11.5	5.5
Netherlands " "	1854-1938	6.4	6.4	-	-
U.S. " "	1885-1939	m[2]	-	-	-
British Marine Obs.	1945-1956	1.7	-	-	1.7
	1956-1961	-	-	-	1.3
German Marine Obs.	1949-1954	0.5[3]	-	1.2	-
	1955-1960	-	-	1.8	-
Netherlands Marine Obs.	1945-1955	0.3[3]	0.7	-	-
	1956-1960	-	0.7	-	-
U.S. Marine Obs.	1945-1960	-[4]	-	-	-
Japanese Marine Obs.	1937-1953	0.8	-	-	-
" Whaling Fleet Obs.	1946-1956	0.01	-	-	-
All decks (29.0 million cards)		18.1	15.9	14.5	11.4

1) Two decks 5.5 + 0.3 million cards; duplicate data possibly included.
2) 2 million observations on microfilm.
3) North Atlantic Ocean not included.
4) Observations of intake temperature not suitable for HSSTD-Project.

The various data of respective nationality are distributed differently over the three main oceans, according to the different economical interests of the shipping concerned. In order to secure therefore a widest possible coverage of data over all oceans, and this in all individual years during the period of record, the available volume of 29 million cards should entirely be used as a basis. Not all these observations need, however, to be processed. The large density of data in some highly frequented shipping lanes permits the selection of a representative network of separate small areas for which monthly means can be prepared, leaving out data from the areas in between. Furthermore, when sufficient data from one deck are already available in a given selected area, data from other decks need not to be used, if costs can be saved in this way. These possibilities to reduce the amount of work - which is very important in view of the big scope of the HSSTD-Project.- are taken into account in the subsequent proposals concerning the selection of representative squares and the indication of possible data processing centres. As a result, a suitable selection of about 23 million cards, or 80 per cent of the total volume available, may prove to constitute a sufficient quantity for the preparation of significant monthly mean data for individual years over as many as possible ocean areas.

None of the samples of basic data, which are preserved in each of the above mentioned countries, contains however a sufficient number of observations in all ocean areas and over all years to enable the carrying out of a project, as general as the HSSTD-Project. The various samples should be combined in one way or other.

8.2 Period of record to be included in the HSSTD-Project

The total volume of data, which is available in the respective countries of origin, permits the envisaged "world marine records" of the HSSTD-Project to be extended over the period from 1860 to 1960 inclusive. Sea surface temperature means for individual months cannot be considered representative, when based on less than 20 observations per selected square. (See para's 4.1, 4.2 and 4.3). Despite this criterion, the distribution of data from certain representative test areas over the individual years did not indicate the existence of a limiting year within the period 1860-1960, before which monthly means of the sea surface temperature would generally lose their significance. (See para 3.3). All years can therefore be included.

It is recommended to overlap the HSSTD-Project with the Scheme of Marine Climatological Summaries of Res. 35 (Cg-IV) at least for a period of 10 years, spanning 1951-1960; this, in order to enable the computation of factors, by means of which the averages which also include intake temperatures could be reduced to averages which are only based on bucket temperatures (see para's 3.2 and 3.4). For this purpose use should be made of the sea surface temperature data kept in the Fed. Rep. of Germany, the Netherlands and U.K. respectively. Indeed, these data were not copied to the U.S., while the original U.S. data refer to intake temperature.

8.3 Selected representative areas

A selection of representative areas for monthly sea surface temperature means was made on the basis of a detailed study of the spatial distribution of available data (as kept by the various countries of origin), taking into account mean gradients of the sea surface temperature over ocean areas as well as the requirement for permitting the study of details of local climatic variations of this temperature. The selected areas are indicated on Chart 5 which contains the following information (see para 4.5):

(i) selected representative areas for which significant sea surface temperature means can be prepared. These areas are indicated by means of full contours and a dot in the centre.

(ii) ten-degree or five-degree squares for which no significant monthly means can be computed due to a general paucity of data. These squares are left blank on the Chart, or they are hatched.

(iii) ocean regions from which numerous marine data are available (highly frequented shipping lanes) and in which a finer resolution of areas to be selected at the computing stage should be tried out on the basis of (1) the scientific requirements for studying local phenomena in detail and (2) a detailed knowledge of the data distribution in one-degree squares and over all years. These ocean regions are indicated by shaded areas.

8.4 Parameters added to the HSSTD-Project

8.4.1 Air temperature

This element can easily be processed together with the sea surface temperature without increase of costs. Even if monthly means of the air temperature were not to be published, their preparation would nevertheless be of great value in view of the use which is made of this parameter for assessing the representativity of sea surface temperature means during the execution of the HSSTD-Project (see para 6.2, 7.1).

8.4.2 Humidity

Insufficient quantities of humidity data are available over the period 1860-1939. Since 1949, several humidity parameters are used in punched cards: wet bulb temperature (generally), dew point (partly), relative humidity (partly), specific humidity (partly). A decision on the parameter to be used is needed before data on humidity could be added to the HSSTD-Project (see para 7.2), but it should be realized that important conversion computations may be involved.

8.4.3 Surface wind velocity

If this parameter is added to the HSSTD-Project, it is recommended to prepare monthly mean wind velocities only for the small representative areas which generally contain a large number of data per individual month.

For the larger selected areas (5° or 10° squares) which generally contain a comparatively small number of observations, the computed monthly mean wind velocities may often not be representative.

The question of representativity needs still to be studied (see para 7.4).

8.4.4 Vector standard deviation of the wind

Before a decision is made concerning its conclusion in the HSSTD-Project (see para 7.5), it is recommended to have a study conducted on the usefullness of the vector standard deviation of the wind as a statistical parameter for the study of surface wind distributions. This suggestion is made in view of the comparatively high costs involved in the computations.

8.4.5 Scalar wind speed

This element could, in addition to the air temperature, easily be processed together with the sea surface temperature without increase of costs. Because of the strong correlation of this element and the sea surface temperature a combined processing is considered to be indispensable for a careful assessment of the representativity of sea surface temperature means.

It is therefore recommended to add the scalar wind speed as a parameter to the HSSTD-Project (see para's 6.2, 7.3).

8.5 Conversion of units

Mean wind forces expressed in Beaufort numbers can be converted with great accuracy into mean wind speeds in meters per sec by means of a linear regression. The regression formula is given in para 6.3. It is therefore not necessary to convert individual Beaufort wind forces before a tabulation of the data is made.

9. General processing scheme

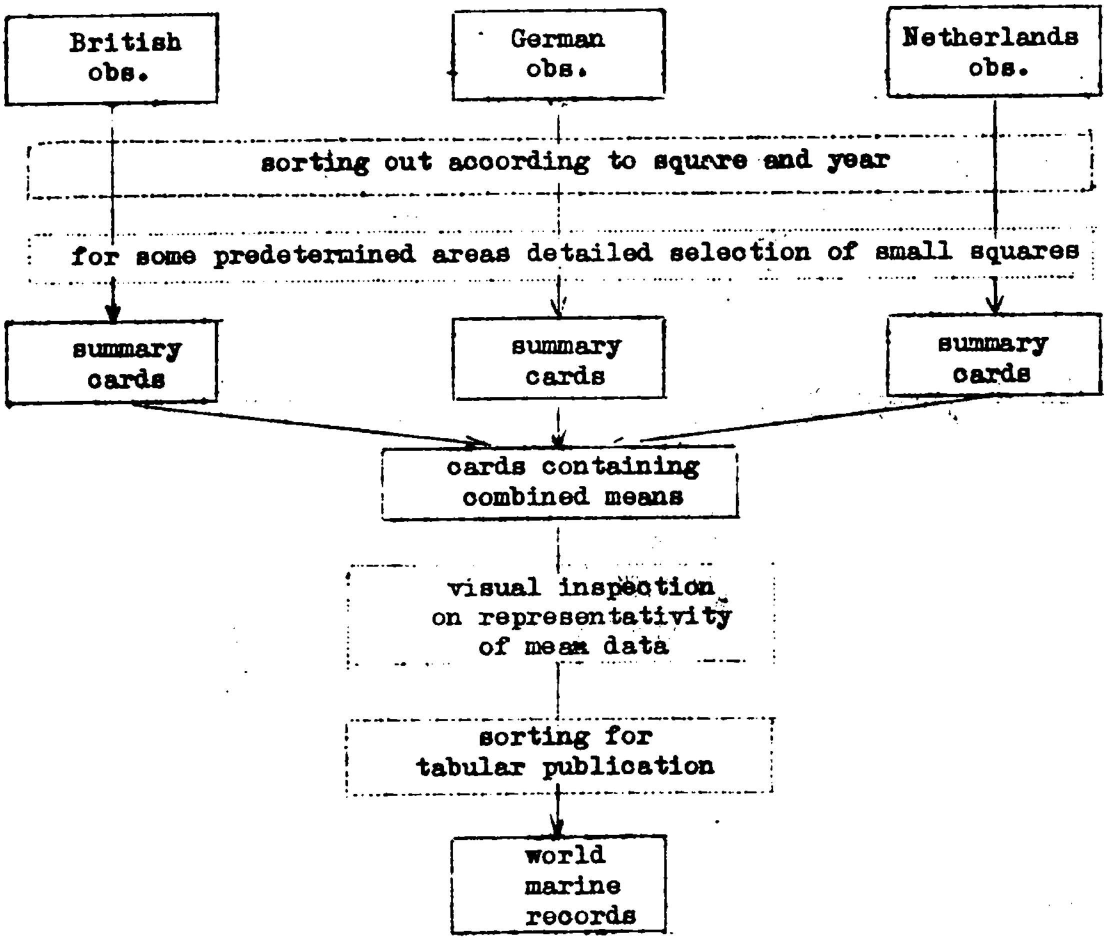
Basic data: mainly one deck of British observations, one deck of German observations, one deck of Netherlands observations. The columnar alignment of the punched cards of the three respective decks is different; also, different units for temperature are used. At data centres the decks are normally stored in boxes per Marsden square and per calendar month.

9.1 The data processing scheme will include the following phases.

phase 1. Date from each of the available decks are separately sorted out according to representative square, individual year (and calendar month, if needed).

1.a (manual treatment) For some ocean regions, indicated on Chart 5, where many observations are generally available per one-degree square, a detailed selection of representative squares may be made on the basis

GENERAL PROCESSING SCHEME



of the distribution, over individual years and months, of data in certain preselected test squares in the area.

phase 2. Summary cards are prepared for each monthly sample of data.

phase 3. Corresponding summary cards from different decks are combined into punched cards containing monthly averages and total numbers of observations. The summary cards may be prepared at a second data centre and then sent to the centre which takes care of the combined processing.

phase 4. (manual treatment) The monthly averages are investigated manually on their representativity; whenever necessary, the respective summary cards are investigated and, in cases of doubt, also the original observations. Doubtfull data are weeded out.

phase 5. The punched cards containing approved mean data are sorted into a tabular arrangement necessary for printing the final "world marine records". This phase may be executed at still another data centre which takes care of phase 6.

phase 6. Printing of the resulting "world marine records".

9.2 Lay-out of summary card

Columns	Element	
1, 2	year	
3, 4	month	
5, 6, 7	ten-degree square	
8	five- degree square	alternatively used
9, 10	two-degree square	alternatively used
11, 12	one-degree square	alternatively used
13, 14, 15	selected square number	
16, 17, 18	sum latitudes within square	based on number of SST data
19, 20, 21	sum longitudes within square	based on number of SST data
22-26	sum sea temperatures	
27, 28, 29	total no. sea temp. obs.	
30-34	sum air temperatures	
35, 36, 37	total no. air temp. obs.	
38-41	sum Beaufort wind forces	
42, 43, 44	total no. wind obs.	
45-50	sum north components of wind	
51, 52, 53	total no. of north components	
54-59	sum east components of wind	
60, 61, 62	total no. of east components	
79, 80	code figure for summary punched card	

Provision is made for inclusion of humidity data. The standard vector deviation cannot be included; a separate summary card should be used for this parameter.

9.3 Lay-out of card containing monthly means

Columns	Element
1, 2	year
3, 4	month
5, 6, 7	ten-degree square
8	five-degree square } alternatively used
9, 10	two-degree square } alternatively used
11, 12	one-degree square } alternatively used
13, 14, 15	selected square number
16, 17, 18	mean latitude within square (0.1 degree)
19, 20, 21	mean longitude within square (0.1 degree)
22, 23, 24, 25	mean sea temperature (0.01°C)
26	blank
27, 28, 29	total no. sea temp. obs.
30, 31, 32, 33	mean air temperature (0.01°C)
34	blank
35, 36, 37	total no. air temp. obs.
38, 39, 40	mean scalar wind speed (0.1 m/s)
42, 43, 44	total no. wind obs.
45, 46, 47	mean vector wind speed (0.1 m/s)
48, 49, 50	mean vector wind direction (whole degrees)
79, 80	code figure for punched card

Columns are available for including mean humidity data and data on the vector standard deviation, if needed.

10 Possible data processing centres

10.1 Division of work on the basis of availability of basic data

As a first approach we may consider the possibility of concentrating the processing of the data at those centres which preserve the largest volume of data. As regards the earlier period of record, 1860-1939, suitable centres appear to be the N.W.R.C. (U.S.A.) and the Seewetteramt (Fed. Rep. of Germany), which preserve together the total volume of available data from this period. Since the deck of German observations, which was copied for the U.S.A. in 1946, was not administrated, this approach inevitably leads to the need to have all German data processed at the Seewetteramt.

As the various decks of observations from the period 1947-1960 are not concentrated in one of these data centres, other arrangements must be made for the processing of these data.

The following division of work is then obtained.

For the period 1860-1939:

N.W.R.C. (U.S.A.)	- processing of 9.0 million British and Netherlands data from all oceans and, possibly, the microfilmed U.S. data from the Pacific Ocean (see para 4.6).
Seewetteramt (Fed. Rep. of Germany)	- processing of 11.5 million German data from all oceans.

For the period 1947-1960:

Met Office (U.K.) K.N.M.I. (Netherlands) Seewetteramt (Fed. Rep. of Germany)	- processing of decks of available national data from all oceans
N.W.R.C. (U.S.A.)	- processing of decks of Japanese data kept by the U.S.A.

Entire period 1860-1960:

N.W.R.C. (U.S.A.)	- printing of the resulting "world marine records" for all oceans. This proposal is made with a view to the experiences gained in the U.S.A. with respect to the printing of the World Weather Records.

At each data centre summary cards will have to be prepared from the available data. These cards should then be sent to a "main centre", where the summaries from the various decks will have to be combined.

At this stage of our reasoning we run into certain difficulties as regards the manual operation of the climatological work involved.

For each of the two periods of record the data to be processed are almost equally divided between the respective data centres. This means that all problems which arise with respect to the phases 1a (detailed selection of representative squares) and 4 (examination of the representativity of computed monthly means) of the General Processing Scheme will have to be discussed amongst those carrying out the computation. Many of these problems can hardly be solved by correspondence; consequently, this approach would inevitably lead to a less efficient execution of the phases 1a and 4 which constitute - it should be stressed - nevertheless the most important phases of the HSSTD-Project. This difficulty can be solved by making the following special arrangement for the computational part of the processing.

10.2 Division of responsibility for the computational work

Principles 1. Three data centres are made responsible each for the computation of historical sea surface temperature data for one of the following three main ocean areas: Atlantic, Indian and Pacific Ocean.

2. At each centre a sufficient volume of data should be kept from the ocean of its responsibility to enable the carrying out of the phase 1a of the General Processing Scheme (detailed selection of representative squares in given ocean areas) on the basis of the data preserved by the centre.

3. As regards the execution of phase 4 of the General Processing Scheme (the examination of the representativity of computed monthly means) a large advantage would be gained, if the observations which are kept at the centre from the ocean of its responsibility were already carefully examined and checked, because of their use for the preparation of a marine climatological atlas. Duplication of a substantial amount of work may thus be avoided.

4. The printing of the complete set of the resulting "world marine records" could be given to one centre, e.g. the N.W.R.C. (U.S.A.) for the same reasons as stated in para 10.1.

These principles logically lead to the following selection of possible data processing centres (see Chart 9).

Atlantic Ocean,
North Sea, Caribian Sea : Seewetteramt (Fed. Rep. of Germany)

Indian Ocean,
Red Sea, Mediterranean : K.N.M.I. (Netherlands)

Pacific Ocean,
Chinese Sea, Austr.Waters : N.W.R.C. (U.S.A.)

Explanation (regarding the period of record 1860-1939)

Atlantic Ocean

a) 71 per cent of the available data from the period 1854-1939 is preserved at the Seewetteramt. This volume already permits to carry out phase 1a (principle 2).

b) The Seewetteramt is engaged during the past 16 years in a study, similar to the HSSTD-Project, with respect to the Atlantic Ocean (see para 5, (v)). In particular, the studies for a detailed selection of representative squares for which monthly means can be computed in the light of the HSSTD-Project, should tie in with the studies already made at the Seewetteramt.

c) The number of German observations in the North Sea and in many ten-degree squares of the Atlantic Ocean may already be sufficient to compute significant monthly sea surface temperature means. Therefore, not all available British and Netherlands data from this ocean may be needed to supplement the German data. The Seewetteramt seems to be the most suitable centre to determine from which ten-degree squares a supplement of data is required.

d) Since 1951, when the Netherlands data were copied for the U.S.A., the Netherlands have prepared frequency distributions of the sea surface temperature per two-degree square and per calendar month for the North and South Atlantic Ocean (unpublished). Doubtful data were weeded out. Phase 4 of the General Processing Scheme may be facilitated when these data are used, if Netherlands observations are required to supplement the German data.

Indian Ocean

a) 94 per cent of the available data from the period 1854-1939 is preserved at the K.N.M.I. This volume already permits to carry out phase 1a (principle 2).

b) During the preparation of the Netherlands marine climatological atlas for the Indian Ocean (1956) the available observations were carefully examined and checked. The working sheets and the results of many published and unpublished detailed studies on the significance of anomalous features which were discovered are still preserved at the K.N.M.I. Phase 4 of the General Processing Scheme will certainly be facilitated by using this material.

c) Supplementation with data kept at other centres will probably be needed for just a few ten-degree squares, as far as the period 1860-1939 is concerned.

Red Sea and Gulf of Aden

The large volume of German observations alone, as well as the large volume of Netherlands observations alone, would suffice to compute significant monthly means for the HSSTD-Project. The Netherlands data are chosen because they have already carefully been checked when used for the preparation of the Netherlands marine climatological atlas for this sea area (1949). They may, however, easily be supplemented with British and German observations in the ten-degree square, which covers the interesting area of upwelling off Aden and in which a finer resolution may be required of squares for which monthly means are computed.

Mediterranean

For the eight squares which were selected in the present study and which correspond to the squares selected by the Netherlands in the light of its responsibility according to Res. 35 (Cg-IV), the same arguments hold true as given for the Indian Ocean (under b and c) and for the Red Sea.

Chinese Sea and Australian Waters

a) The British and Netherlands observations over the period 1854-1939, which are preserved by the U.S.A., have already carefully been checked before reproduction to the U.S.A., when used for the preparation of respective national marine climatological atlasses. With the help of these observations, and the deck of Japanese Marine Observations which is preserved by the U.S.A., a finer resolution of representative squares in the Chinese Sea can be investigated.

b) Supplementation of the data in the Chinese Sea with German observations kept at the Seewetteramt, may probably not be needed. All phases of the General Processing Scheme can therefore be executed in the U.S.A. without complications.

Pacific Ocean

Because of their very small number, German data from the period 1860-1939 cannot effectively be used for the greater part of the Pacific, except in the ten-degree squares off the west coasts of South and North America where a large number of this data is available (at the Seewetteramt). All other data are preserved by the U.S.A.; British, Japanese and Netherlands observations on punched cards and U.S. marine observations on microfilm.

The special problems which are met with regard to preparing significant monthly or seasonal means for this ocean can obviously only be solved within the centre which preserves the large majority of data.

Period of record 1947-1960

As regards the preparation of summary cards from basic national data the same arrangement should be made as outlined in para 10.1. The summary cards should be sent to the data centre which is made responsible for the computation of HSST data from the ocean area concerned.

10.3 Recommendations

Summarizing the above considerations it is recommended :

i) to arrange for the preprocessing work to be carried out by the following four countries:

Seewetteramt	(Fed. Republic of Germany)
K.N.M.I.	(Netherlands)
Meteorological Office	(U.K.)
N.W.R.C.	(U.S.A.)

ii) to concentrate the actual computational work of HSST mean data in three of the above centres, according to the following areas of responsibility:

Seewetteramt (Fed. Republic of Germany)	for Atlantic Ocean
K.N.M.I. (Netherlands)	for Indian Ocean and Mediterranean
N.W.R.C. (U.S.A.)	for Pacific Ocean

(Note: the exact boundaries of the ocean areas of responsibility are indicated on Chart 9)

iii) to arrange for N.W.R.C. (U.S.A.) to print the complete set of the resulting "World Marine Records".

11. Estimate of the amount of work as a basis for calculation of costs.

11.1 Project I: sea surface temperature

In this project the air temperature and the scalar wind speed can also be processed without increase of costs. Indeed, these two elements are needed for checking the representativity of sea surface temperature means during the execution of the project. (Humidity may also be included).

It is assumed that not all available data are needed to compute significant monthly means of the sea surface temperature. This holds particularly true for the Atlantic Ocean, where the German observations could be supplemented with comparatively few British and Netherlands data, and for the Indian Ocean, Red Sea and Mediterranean, where the data preserved by the Netherlands may possibly be supplemented with some German data from earlier years in the period 1860-1939.

Tables 1a and 1b summarise, for the two periods 1860-1939 and 1947-1960 respectively, the number of punched cards which will be used for sorting, tabulating and computing respectively and by the respective data centres. An entry "pro memoria" is made as regards the U.S. marine observations on microfilm from the Pacific Ocean.

As regards the first sorting it is assumed that the original data are stored per ten-degree square and per calendar month.

The summary cards which are to be exchanged are assumed to be sorted per square, per calendar month and per year.

Tables 2a and 2b summarize, for the two periods 1860-1939 and 1947-1960 respectively, the number of hours of sorting, tabulating and computing respectively at the respective data centres.

For sorting a medium speed sorting machine with a capacity of 30,000 cards per hour is considered. The estimate of hours is based, however, on an effective sorting speed of 10,000 cards per hour. In this way due allowance is made to the extra sorting work involved in the detailed selection of representative squares on the basis of earlier test sortings. It should be noted that the effective sorting speed is generally reduced by the fact, that the sample of data is to be broken down into many small parcels.

For this Project a tabulator with comparatively small capacity suffices. The tabulating hours which are given refer to Bull Tabulator, B.S. 92.

The computing of mean values and the conversions from Fahrenheit into Censius and Beaufort into meter per sec, are carries out, in these considerations, by a combination of the above mentioned Bull Tabulator and a Bull Gamma, No. 3.

The output from the respective data processing centres is also given in these Tables, in order to enable assessment of the printing costs. Data to be published are:

mean latitude within square }
mean longitude " " } (large squares only)

number of observations of sea surface temperature

mean sea surface temperature

mean air temperature }
mean scalar wind speed } (not published in Project I)

Table 3 summarizes the results from the Tables 2a and 2b. In this Table an estimate is also given of the extra work involved in preparing monthly means for the Atlantic Ocean for the years 1914-1916 and 1919-1921 in which German data are generally missing. Inclusion of these years in the "World Marine Records" would necessitate the sorting of all available British and Netherlands data from this Ocean.

It should be noted that the 14 squares in the Atlantic Ocean, for which the Seewetteramt (ref.4) has already published sea surface temperature means for individual months and which still form the object of a national study in the Fed. Rep. of Germany, are not included in the present proposals. The supplement of mean data from the above mentioned years during World War I should, however, also include these squares. The same holds true for the period 1947-1960.

In the estimate of costs should be included 1.5 man-year for a climatologist and also 1.5 man-year for checking the punching of summary cards.

Alternative machines.

The sorting hours could be reduced to about 70 per cent if the sorting machine is directly coupled to a tabulator with large capacity so that the manual work of bringing the small parcels of cards over from sorter to tabulator is disposed of. The per hour costs of such tabulators are, however, so high as compared to those of a more simple tabulator, that no costs will be saved as regards Project I.

The information which is punched on the summary cards could be put on magnetic tape instead. The costs of this method are estimated to be about the same for Project I, because of the comparatively small number of summary cards involved. The use of magnetic tape necessitates, however, a more expensive computer, having more possibilities than the tabulator on which the calculation was based.

The information given in Tables 2 and 3 may therefore be regarded as a basis for the calculation of minimum costs.

Project I   Table 1a   Period 1860-1939

Data centre	no. squares	no. cards for sorting x 1000	no. cards for tabulating x 1000	no. of summary cards	no. of summ. cards to be combined at centre	no. of cards containing monthly means	no. squares	no. years
U.K.	a. 60	200	200	56.160	-	-	-	
F.Rep Germany	a. 162 i. 20 p. 36	7.500 60 442	7.210 60 430	139.968 17.280 31.104	Atl.Oc. 252.288	139.968	162	72
Neth.	a. 60 i. 111	500 4.438	500 3.540	56.160 103.896	Ind.Oc. 121.176	103.896	111	78
U.S.A.	p. 55	1.679 +m	1.500 +m	51.480	Pac.Oc. 82.584	51.480	55	78
		14.819	13.440	456.048	456.048	295.344	328	

a. = Atlantic Ocean
i. = Indian Ocean (including Red Sea and Mediterranean)
p. = Pacific Ocean

m = on microfilm

Project I   Table 1b   Period 1947-1960

Data centre	no. squares	no. cards for sorting x 1000	no. cards for tabulating x 1000	no. of summary cards	no. of summ. cards to be combined at centre	no. of cards containing monthly means	no. squares	no. years
U.K.	a. 176 i. 111 p. 55	2.700	1.800	29.568 18.648 9.240	-	-		14
F.Rep. Germany	a. 176 i. 111 p. 55	3.000	2.000	29.568 18.648 9.240	Atl.Oc. 88.704	29.568	176	14
Neth.	a. 176 i. 111 p. 55	1.400	900	29.568 18.648 9.240	Ind.Oc. 55.944	18.648	111[2]	14
U.S.A.	p. 30[1]	766[1]	500	2.520	Pac.Oc. 30.240	9.240	55	14
		7.866	5.200	174.384	174.888	57.456	342	

1) Chinese Sea,(Jap. Mar. Obs.)and W.Pac.

2) Including Red Sea and Mediterranean.

Project 1 Table 2a Period 1860-1939

Data centre		sorting		tabulating		computing (combination of summ. cards)			output (monthly means)		
	no. of squares	no. of cards x 1000	hours	no. of cards x 1000	hours	no. of cards	hours: sorting	hours: computing	no. of cards	no. of squares	no. of years
U.K.	a. 60	200	80	200	66	-			-		
F.Rep. Germany	a. i. 218 p.	8.002	3.200	7.700	2.567	Atl.Oc. 252.288	50	86	139.968	162	72
Neth.	a. i. 171	4.938	1.975	4.040	1.347	Ind.Oc. 121.176	24	42	103.896	111	78
U.S.A.	p. 55	1.679 +m	672 +m	1.500 +m	500 +m	Pac.Oc. 82.584	16	28	51.480	55	78
		14.819 +m	5.927 +m	13.440 +m	4.480 +m	456.048	90	156	295.344	328	

Project I   Table 2b   Period 1947-1960

Data centre	no. of squares	sorting: no. of cards x 1000	sorting: hours	tabulating: no. of cards x 1000	tabulating: hours	computing (combination of summ.cards): no. of cards	computing: hours: sorting	computing: hours: computing	output (monthly means): no. of cards	no. of squares	no. of years
U.K.	a. i. p. } 342	2.700	1080	1.800	594	-		-	-		
F.Rep. Germany	a. i. p. } 342	3.000	1200	2.000	660	Atl.Oc. 88.704	17	30	29.400	176	14
Neth.	a. i. p. } 342	1.400	560	900	297	Ind.Oc. 55.944	11	19	18.648	111	14
U.S.A.	p. 30	766	300	500	165	Pac.Oc. 30.240	6	10	9.240	55	14
		7.866	3140	5200	1716	174.888	34	59	57.456	342	

Project I   All decks   Table 3

Period	sorting		tabulating		computing (combination of summ. cards)			output (monthly means)		
	no. of cards x 1000	hours	no. of cards x 1000	hours	no. of cards	hours: sorting	hours: computing	no. of cards	no. of squares	no. of years
1860–1939	14819 +m	5927 +m	13440 +m	4480 +m	456.048	90	156	295.344	328 1)	78(72)
1947–1960	7866	3140	5200	1716	174.384	34	59	57.288	342	14
1860–1960	22685	9067	18640	6196	630.432	124	215	352.632		92(86)

Extra work involved in preparing monthly means for the Atlantic Ocean for years in which German data are missing.

	squares										
1914–1916, 1919–1921	176	3100	1240	250	83	38.016	4	8	12.672	176	6
		U.K. 26% Neth. 74%				Fed.R. of Germany					

1) minus 14 squares which form the object of a national study in the Fed. Rep. of Germany.

11.2 <u>Project II: air temperature, wind speed, mean surface wind velocity.</u>
There are two problems connected with the addition of the mean surface wind velocity.

a) One needs more observations, especially for the larger selected areas.

b) The tabulator of para 11.1 cannot handle 16 wind directions for the computation of the north and east wind components, and tabulate at the same time other elements like air temperature and scalar wind speed. This means that the cards will have to be run twice through the tabulator.

Because of the problem (b) other types of computers were considered, which would have sufficient capacity to tabulate all required elements. Such computers are for instance I.B.M. 360 model 40, Elliot 503 or Electrologica X8. They can be directly coupled to a sorter with a capacity of 60,000 cards per hour (effective speed 35,000 cards per hour); the output can be punched on cards or fixed on magnetic tape.

These machines are however much too costly to be used for a detailed selection of areas. For this purpose the machines mentioned in para 11.1 should be used.

Since the larger computers can also handle the sea surface temperature, together with the other elements, it is really not possible to estimate minimum costs of Project II. One should look for a computer, large enough to handle the elements of Project II, but small enough to exclude the sea surface temperature.

In the next paragraph therefore, the basis is given for a calculation of the estimated extra computing costs, when the mean surface wind velocity is added to the HSSTD-Project.

11.3 <u>Projects I and II combined: sea surface temperature, air temperature, wind speed, mean surface wind velocity.</u>

If this combined project were carried out with the machines mentioned in para 11.1, we get as compared to Project I

a) addition of about 15% sorting hours (more observations needed);

b) addition of about 15% tabulating hours, plus duplication of the tabulating hours (because of 11.2 (b));

c) no change in computing hours.

The increase of the amount of work has the effect that the combined project will cost about 55% more than Project I, according to European standards. About the same increase of costs is estimated when the larger computers, mentioned in para 11.2, are used.

14 maart 1966 .-.-.-.-. G.Verploegh

REFERENCES

1. J.Bjerknes, 1963 – Climatic change as a ocean-atmosphere problem; Proc. of Rome Symposium on Changes of Climate, UNESCO/WMO.

2. C.E.P. Brooks, C.S. Durst, and N. Carruthers, 1946 – The frequency distribution of winds at a point in the free air; Quart. J. R. Met.Soc. London 72, p.55.

3. H.J.Bullig, 1950 – Ueber Wassertemperaturanomalien des östlichen Atlantischen Ozeans und ihre meteorologische Bedingtheit; Berichte D.f.Wd. in der US-Zone, Nr.12.

4. H.J.Bullig, 1954 – Atlas der Monatswerte von Wassertemperatur, Wind und Bewölkering auf dem Seeweg Europa-Südamerika, D.f.Wd., Seewetteramt, Einzelveröff., Nr.5.

5. H.L.Crutcher, 1957 – On the standard vector-deviation wind rose; J.Meteor. 14, p.28-33.

6. CMM-IV, 1964 – Abridged Final Report, Annex III, p.77.

7. H.Keyer, 1939 – Statistics relating to typhoons; K.N.M.I., No.119.

8. Marine Observer, 1964 – Ships' Weather Messages; M.O. XXXIV, Nr. 206, p.199.

9. K.N.M.I., 1957 – Middellandse Zee, Oceanografische en meteorologische gegevens; K.N.M.I. Nr. 138.

10. H.Markgraf, 1961 – Klimatologie des Mittelmeeres, D.f. Wd., Seewetteramt, Einzelveröff., Nr. 29.

11. M.Rodewald, 1963 – Sea surface temperatures of the North Atlantic Ocean during the decade 1951-1960; Proc. of Rome Symposium on Changes of Climate, UNESCO/WMO.

12. G.Verploegh, 1954 – Een merkwaardige gemiddelde luchtdrukverdeling voor de kust van Somaliland; K.N.M.I. Meded. en Verh. No.59.

13. G.Verploegh, 1960 - On the annual variation of climatic elements of the Indian Ocean; K.N.M.I. Meded. en Verh. Nr. 77.

14. G.Verploegh, 1965 - De Zee, Nr.12. English translation of title: On errors in radio weather messages from ships.

English version submitted to the CMM-IV Working Group on the Collection of Ships' Weather Reports.

15. W.M.O., 1954 - Technical Note No.2 Part 1.

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Distribution of marine observations over the years in some test areas

Indian Ocean, [redacted]

year	Marsden squ. 029 Neth.	Germ.	Brit.	Marsden squ. 434 Neth.	Germ.	Brit.	Marsden squ. 475 Neth.	Germ.	Brit.
1850/59	6			116			202		
1860/69	16			496		22	504		34
1870/79	131			333		16	556	15	188
1880/89	755			121		37	144	42	486
1890/99	1447	3		119		40	212	48	337
1900	144	24						1	13
1	205					22		8	
2	125					13	12	9	
3	187					9		13	
4	194	21						17	23
5	179	36			7			14	39
6	203	82	8		11	13			30
7	226	52	48						19
8	229	63	16		33			21	29
9	286	43	64			2		11	17
1910	295	122	131			12		28	10
11	314	256	120	27	12	11		90	35
12	318	245	102		42	34		52	25
13	349	221	63		16	34		54	21
14	381	373	214	11	30	60		84	18
15	286		36			11			27
16	231		76			12			22
17	161		12			25			
18	2		7			11			
19	60		41						
1920	278		84	11		9			
21	354	33	64			9		14	
22	353	46	114						8
23	244	120	119			25			
24	300	105	111		19	10		19	3
25	410	142	158			18		15	
26	400	69	134					32	11
27	425	98	129			11			
28	424	200	120		14	12		17	8
29	437	223	.79			8		20	9
1930	499	309	1		12	9		35	
31	310	245	14					14	
32	344	86	8		5			6	
33	195	92	27	13		8		4	10
34	296	152	25	8		3		5	
35	272	230	51		6			11	
36	227	287	35	8	6	8		14	
37	321	371	11	11	21			10	
38	300	287	15		8			10	
39		263	11		8			22	
Total	13119	4909	2248	1274	250	514	1630	755	1422

Verschil met CDROM Deck 193:
Verploegh heeft 361 records meer.

Distribution of marine observations over the years in some test areas

Mediterranean, 2° square south of Crete, March

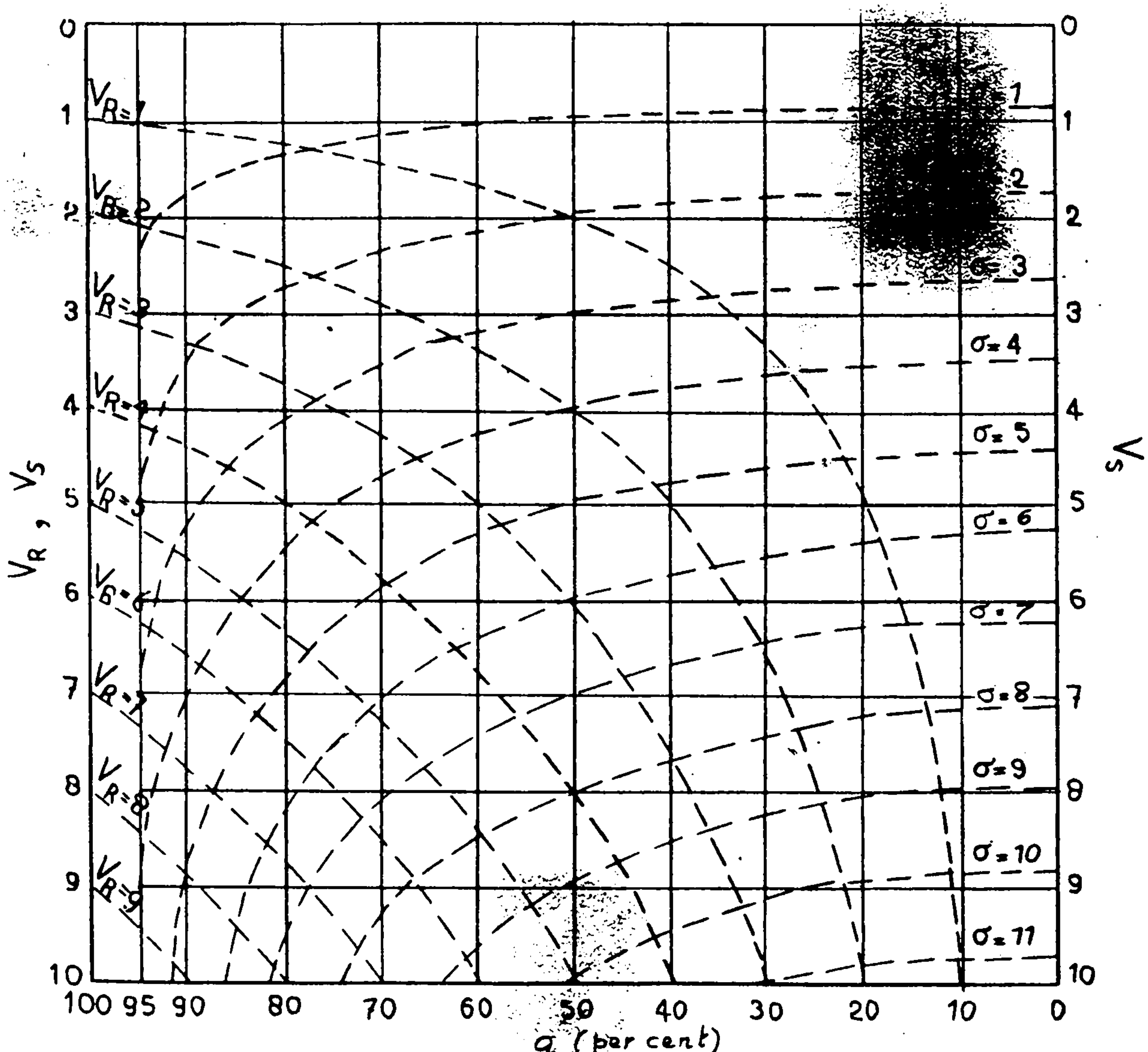
year	Neth.	Germ.	Brit.
1850/59	26		
1860/69	4		
1870/79	13		
1880/89	74		
1890/99	65		
1900	13		
1	1		
2	12		
3	5		
4	19		
5	9		
6	15	6	
7	12	4	
8	17	13	
9	29	5	
1910	13	28	
11	29	25	
12	24	33	
13	32	51	
14	37	72	
15	34		
16	24		
17			
18			
19	24		
1920	14		
21	32		36
22	41	11	22
23	39	17	30
24	24	7	17
25	41	24	21
26	41	2	20
27	39	7	9
28	24	13	12
29	41	28	14
1930	39	16	
31	38	12	3
32	42	8	2
33	43	3	6
34	18	8	2
35	17	6	2
36	7	21	
37	13	51	6
38	7	17	1
39	10	15	
Total	997	503	203

Distribution of the Dutch observations over years and days in the month of July in the sea area bounded by long. 50°E, the equator and the coast of Somaliland. For each year the observations made by the same ship are indicated by the characters A, B, etc. (reproduced from Verploegh, 1954).

Day \ Year	1922	1923	1924	1925	1926	1927	1928	1929
1								
2		1				A B		
3		6 } A				1(1)		
4		2		A B		11(5)(6)		
5				3(2)(1)		7(4)(3)	5 } A	A B
6				7(1)(6)			5	1(1)
7				3 (3)				5(2)(3)
8								6 (6)
9	1 – A		6 } A					3 (3)
10	6		5					
11	6 } B							C D
12	4							1(1)
13		6 } B						6(6)
14		5						6(4)(2)
15							1 } B	
16							3	
17								
18								
19					3			
20					6 } A		6 } C	
21					1		4	
22				4		3 } C		
23				6 } C	5 – B	5		
24				4				
25								
26								
27								2 } E
28								4
29								4 } F
30		6 } C						6
31		3						
Sum	17	29	11	27	15	27	24	44

Distribution of the Dutch observations over years and days in the month of July in the sea area bounded by long. 50°E, the equator and the coast of Somaliland. For each year the observations made by the same ship are indicated by the characters A, B, etc. (reproduced from Verploegh, 1954).

Day \ Year	1930	1931	1932	1933	1934	1935	1936	1937	1938	Sum
1				1 } A						1
2				6	3 } A					10
3			4 } A	3	3					17
4			33							16
5							2 } A			17
6							5			18
7						3 } A				11
8						5		3 } A		14
9								5		15
10	A B						4 –B		3 } A	18
11	3 (3)								4	13
12	6 (6)									11
13	8 (4) (4)									20
14	2 (2)									13
15		2 } A	1 } B							4
16		6	5			5 } B				19
17		3				2				5
18										–
19										3
20	1 –C									13
21										5
22					6 } B					13
23					5					21
24	6 } D									10
25	5									5
26								4 } B		4
27								5		7
28										4
29										4
30			3 } C							15
31			6	3 –B						12
Sum	31	11	22	13	17	15	11	17	7	338



Relation between mean [illegible] wind speed (V_s), mean vecto[illegible] wind velocity (V_r), [illegible] (q) and vector deviati[illegible] the wind (σ), accordi[illegible] Brooks, Durst and Ca[illegible] (1946).

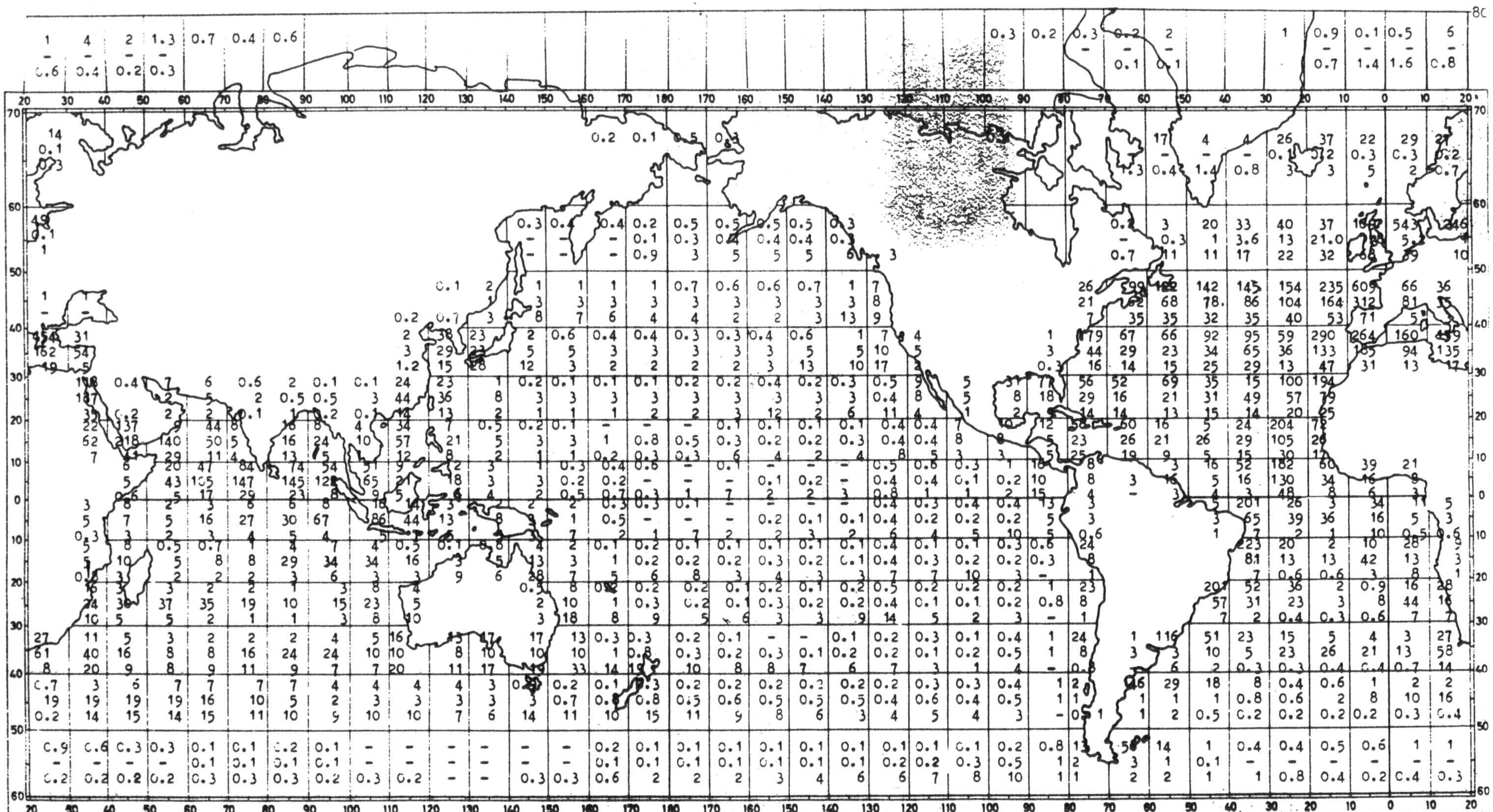


Chart 1 - Numbers of observations (x 1000) per ten-degree square over the period 1854-1939

Above : German obs; middle : Netherlands obs; below : British obs

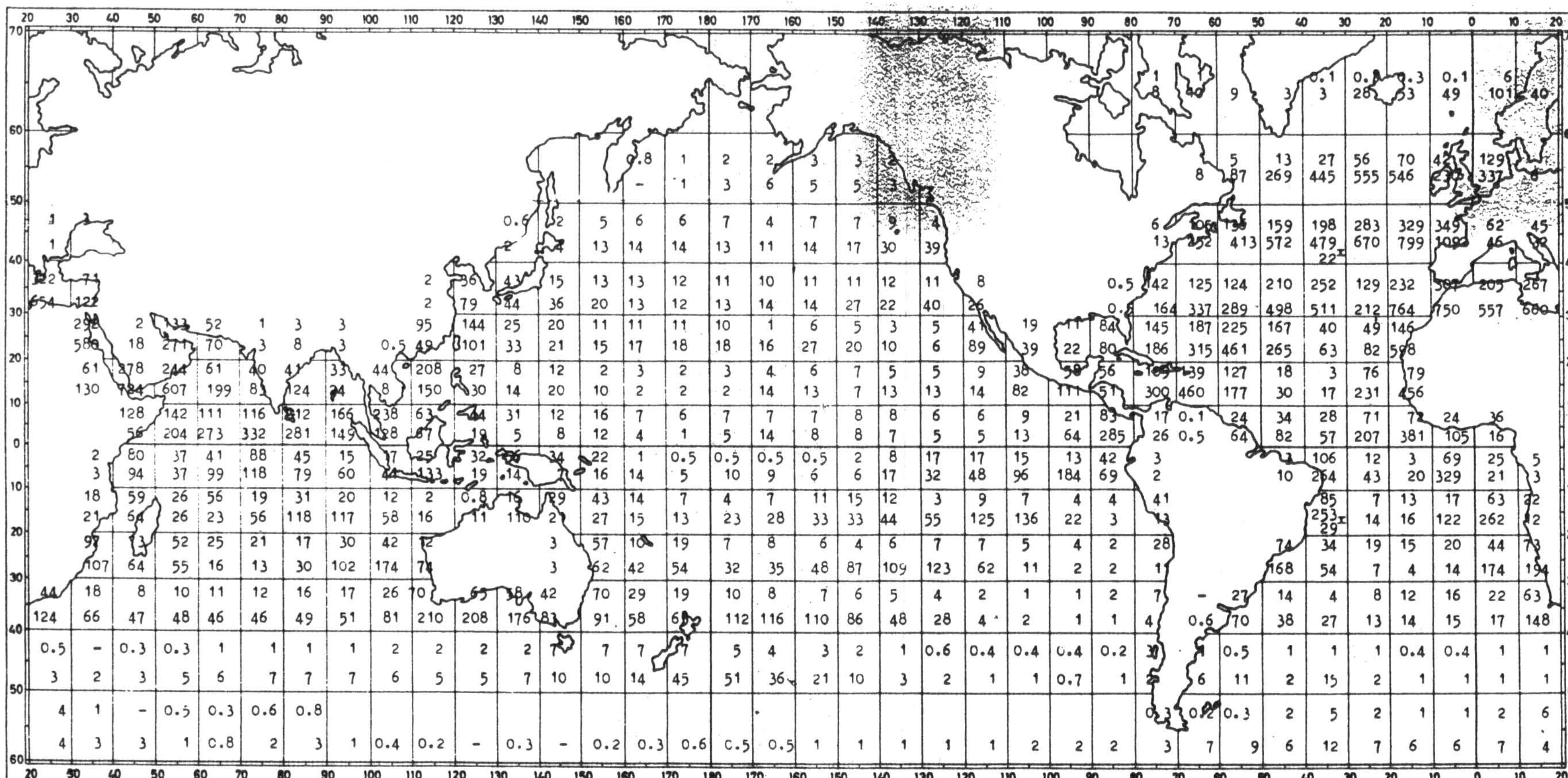


Chart 2 : Numbers of observations (x 100) per ten-degree square over the period 1945-1960

Above : Netherlands obs; below : British obs (including 1961)

(x) German obs in test squares in Atl. ocean

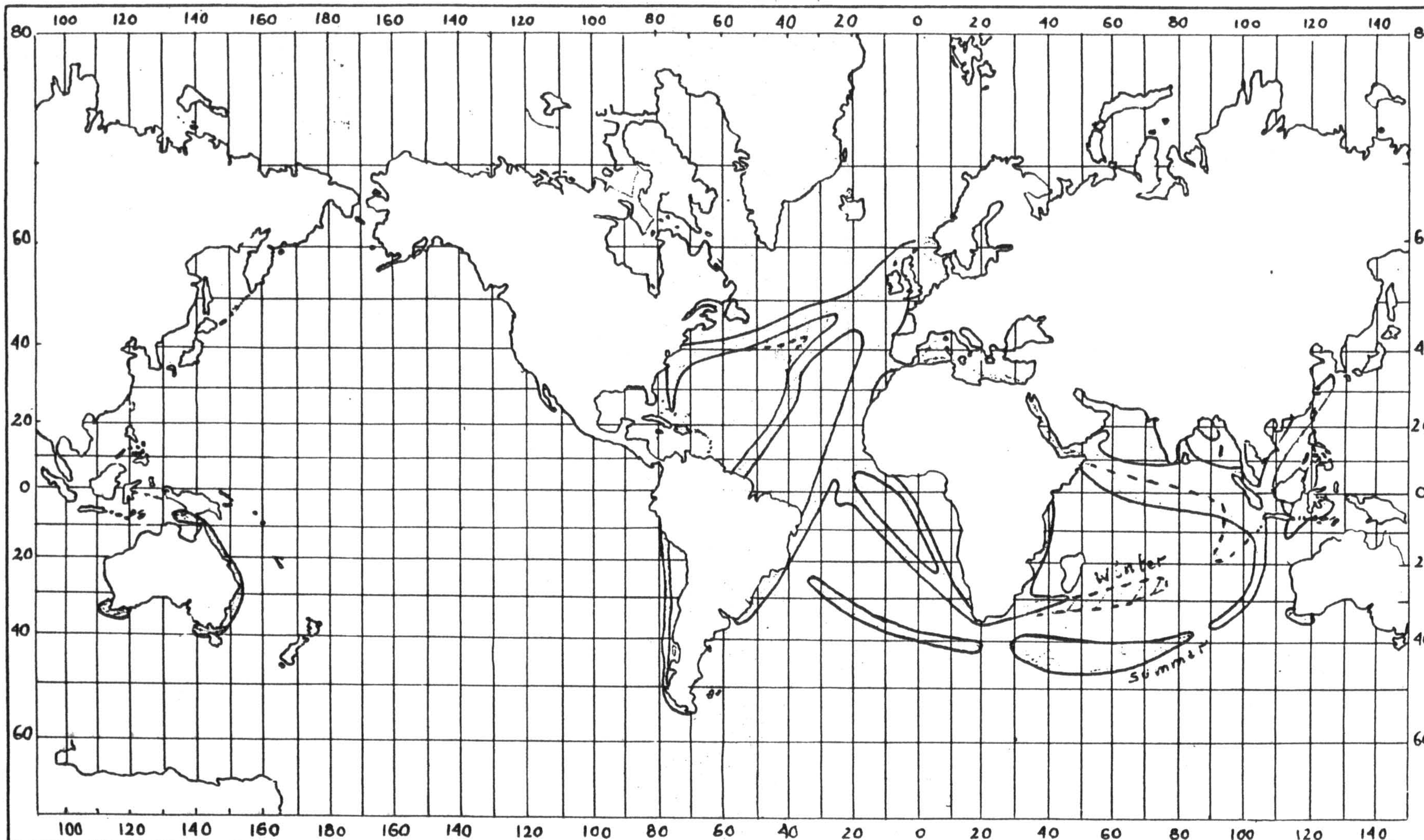


Chart 3 - Areas where more than 200 observations per two-degree square over the period 1854-1939 are available

MAP SHOWING DENSITY OF VOLUNTARY SHIPS REPORTING SURFACE WEATHER OVER THE OCEANS
CARTE REPRESENTANT, POUR TOUS LES OCEANS, LA DENSITE DES NAVIRES QUI TRANSMETTENT BENEVOLEMENT DES DONNEES D'OBSERVATION EN SURFACE

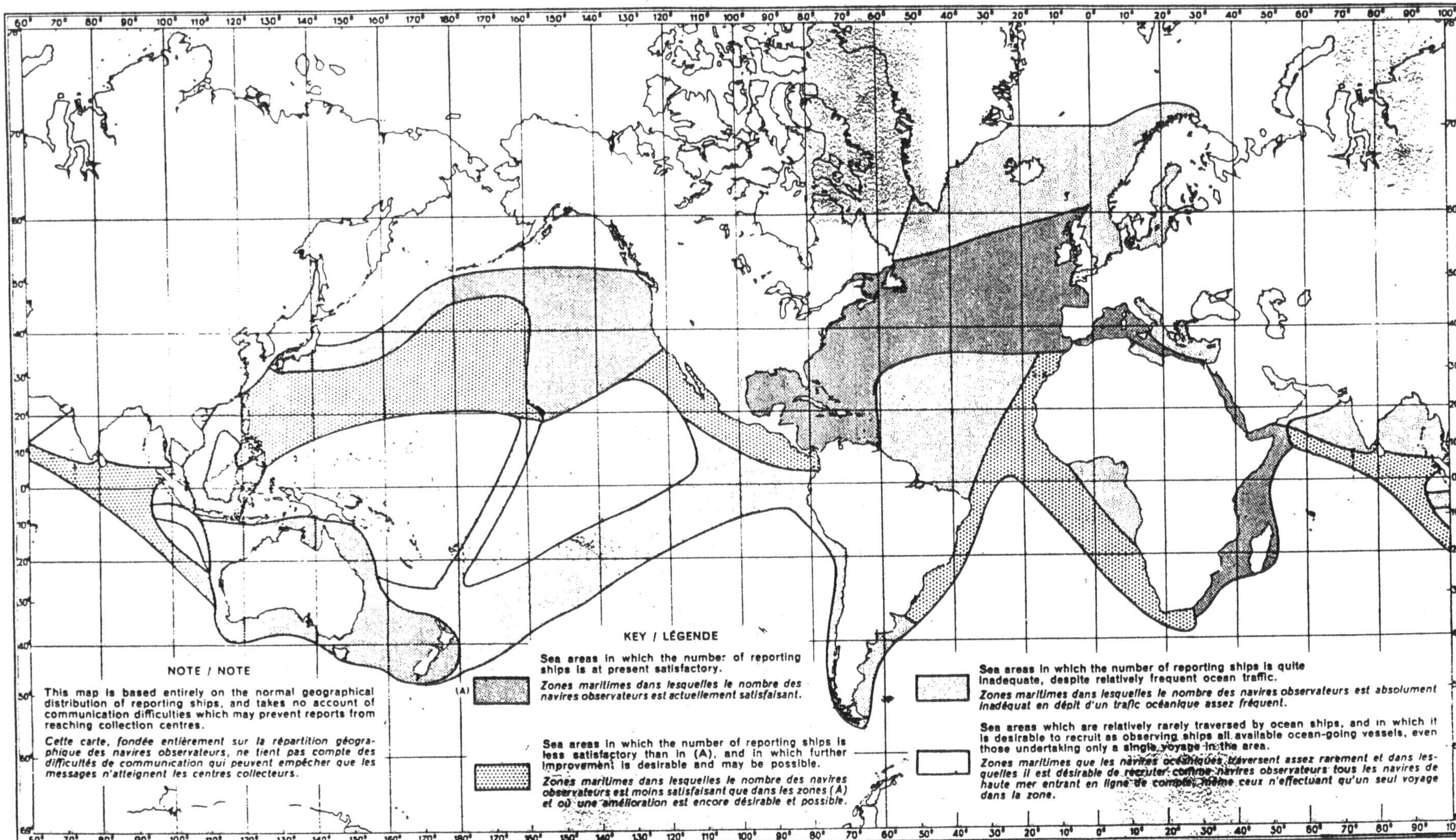


Chart 4

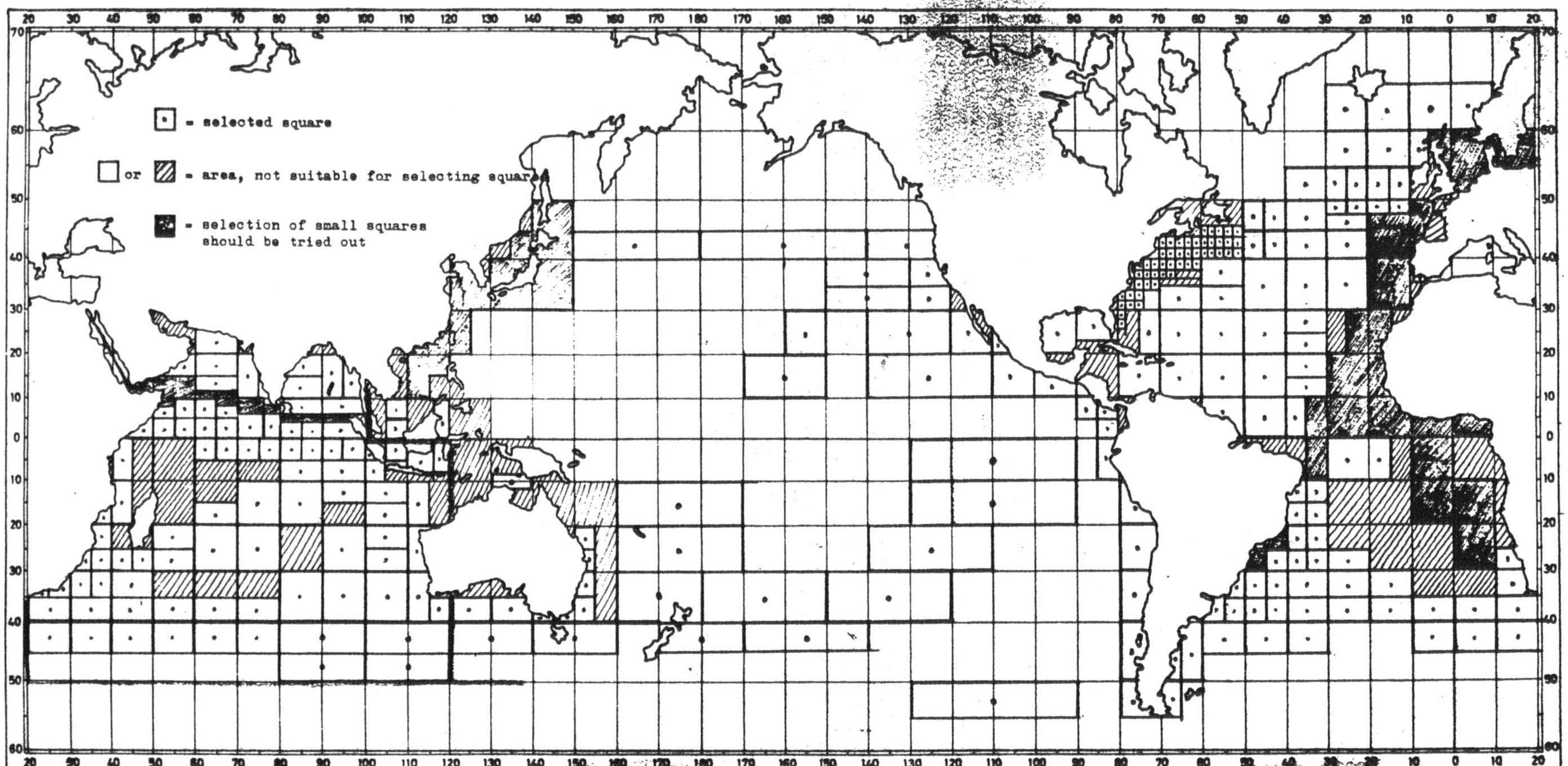


__Chart 9__ - Selected squares for HSSTD-project

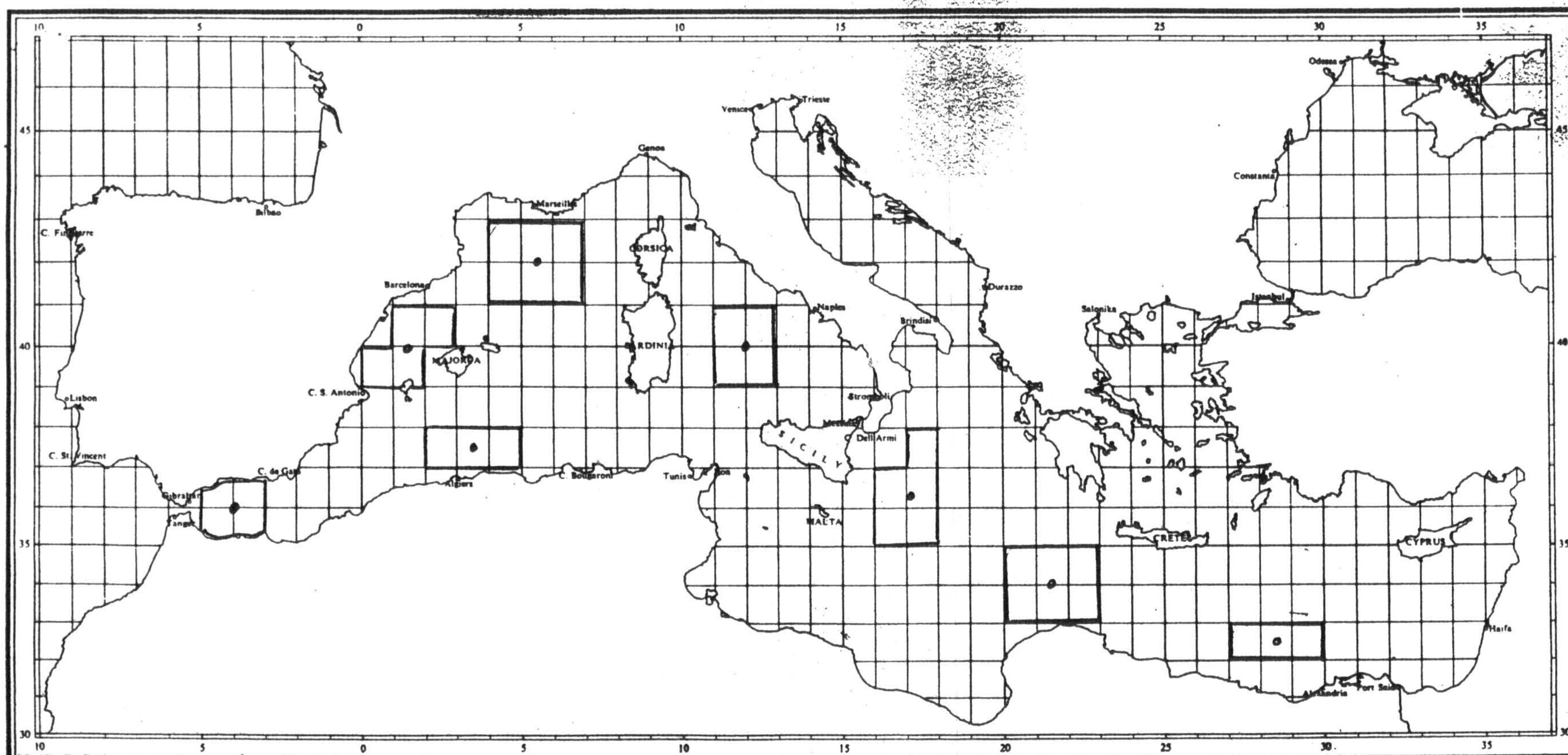
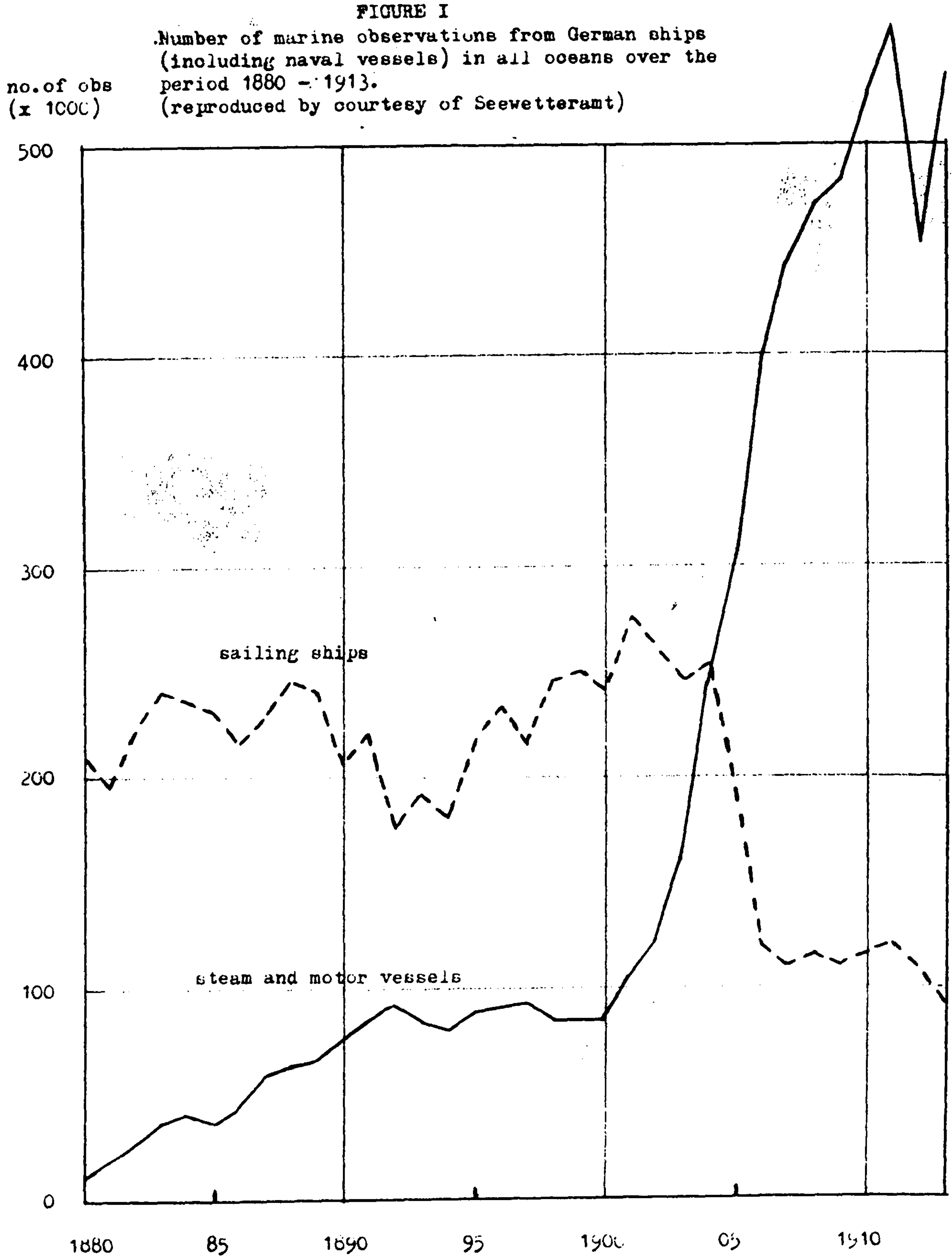


Chart 5a - Selected squares in Mediterranean

FIGURE I

Number of marine observations from German ships (including naval vessels) in all oceans over the period 1880 - 1913.
(reproduced by courtesy of Seewetteramt)



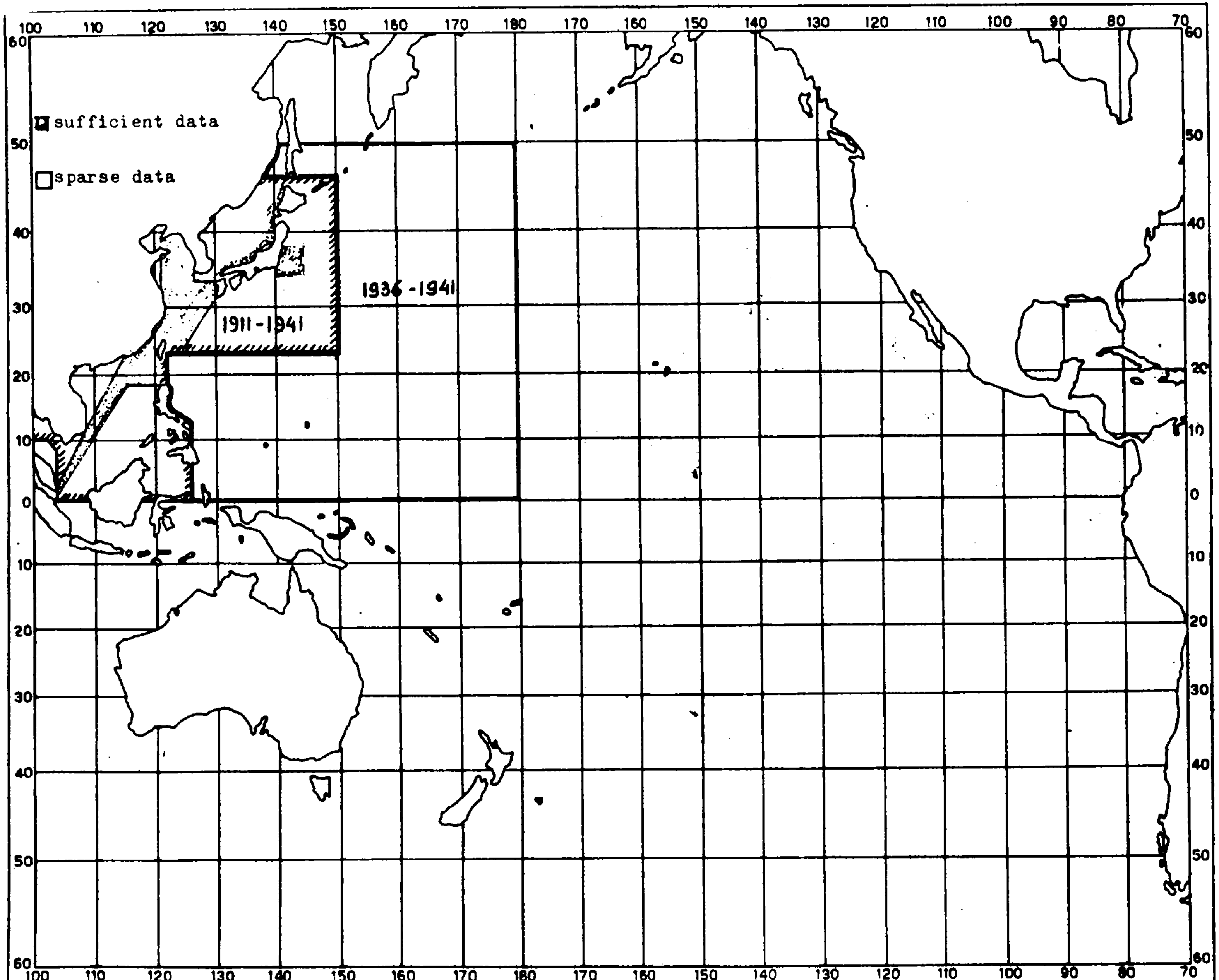


Chart 6 - Areas for which 1°-square SST means for individual months have been published by the Kobe Marine Observatory (Ja-

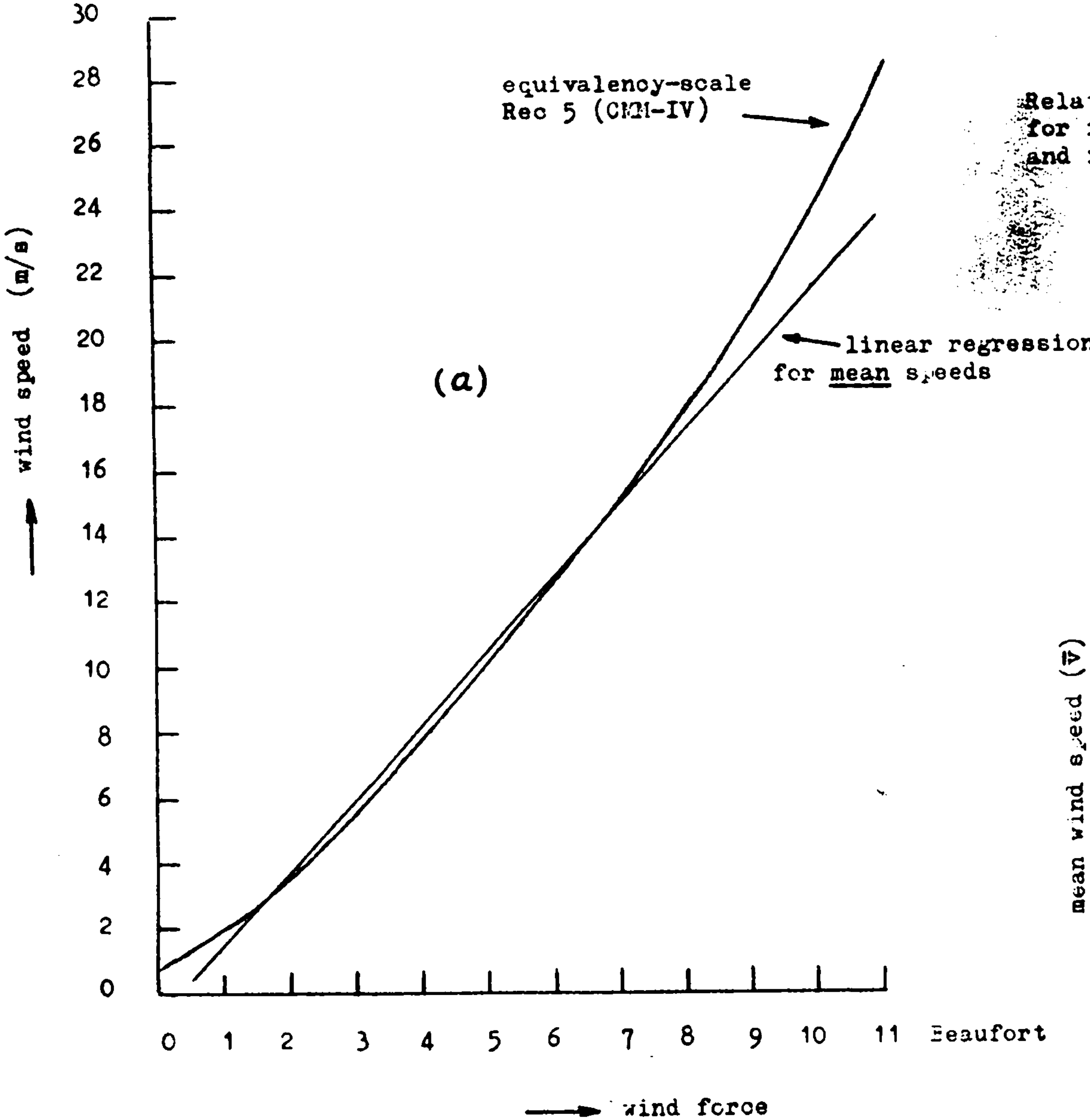


FIGURE II

Relation between wind speed and Beaufort force for individual observations (a) and for mean data (b)