CENTRAL FORECASTING MONITORING NOTE NO. 9

STATISTICS OF ERS-1 SCATTEROMETER WINDS FOR MARCH 1992

INCLUDING A COMPARISON WITH SHIP OBSERVATIONS

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1. Introduction

The European Remote Sensing satellite (ERS-1) was launched in July 1991 and from the following month data have been received at Bracknell. The data include surface wind speeds and directions derived from the scatterometer radar, wind speeds and significant wave heights from the radar altimeter and sea surface temperatures from the Along Track Scanning Radiometer (ATSR). This Note presents statistics of the surface wind speeds and directions from the scatterometer radar.

The scatterometer radar is a three beamed instrument. Microwave radiation transmitted from each of the three antennae (oriented in different directions) is backscattered from wind ripples on the sea surface to the satellite. The backscattered power is a function of, amongst other factors, windspeed and direction at the sea surface. Although the physics of the interaction of a radar beam with a rough sea surface is not well understood, an empirically based relationship between the backscattered power and the wind vector at the sea surface can be determined. Further details are available in the ERS-1 literature.

Products are received as blocks of 19 x 19 observations, with each observation 25 km apart and having a nominal resolution of 50 km. The orbit period is about 100 minutes. Approximately 200,000 observations per day are received, most but not all within 2-3 hours of observation time. The scatterometer shares its transmission with the synthetic aperture radar (SAR) instrument (producing image data) and unfortunately from the Met. Office's point of view the SAR is often operated in the vicinity of UK waters. Hence often scatterometer winds are not available around the UK because of the operation of the SAR.

The Met. Office produces its own set of wind speeds and directions from the backscattered radiation in addition to winds derived by ESA ; the model producing the winds does not produce a unique speed and direction - up to four solutions are possible and two of the solutions are always 180° apart, because for example a westerly wind produces a similar pattern of ripples as an easterly. The Met. Office uses short period forecast surface winds from our own model to help resolve the ambiguity. Until July 1992 ESA have not in general used a forecast and consequently their winds, particularly the directions, are of significantly poorer quality.

Since last summer, plots of the Met. Office derived winds have been produced twice a day for CFO. These were initially used to monitor the quality of the observations but now that the quality has been seen to be acceptable, the charts are used primarily to assist CFO in inferring the surface wind analysis, particularly in areas where there are little or no conventional observations. On several occasions the charts have helped CFO to identify or locate precisely the position of fronts and small scale depressions. An example of a plot of the Met. Office ERS-1 winds (on 13th July 1992) is shown in fig 1.

2. Data

ESA and Met. Office winds, together with model information such as model 10m background and analysis winds interpolated to the observation point, are stored in the Meteorological Data Base (MDB). Note that the ERS-1 winds are modified to be valid at 10m above the sea surface. The background field for ERS-1 winds is a 3-9 hour forecast, the exact forecast length depending on the hour of observation. The analysis is always valid at the main synoptic hour (00, 06, 12, 18z) closest to the observation - so there could be up to three hours difference between the observation and analysis time but only 30 minutes between observation and background. In practice, the statistics for Observation-Analysis have been very similar to those for Observation-Background and so only statistics for the latter are presented here. Observations arriving after the model data cut-off times for the relevent global runs ie the 00 and 12z update runs and 06 and 18z runs, are excluded from the results below since then model information is not available.

Data for March are presented in this Note. On 1st March ESA made a calibration change which affected both ESA and Met. Office winds and on 2nd March a change to the algorithm deriving the Met. Office winds was implemented. Further changes have taken place since the end of March but the basic properties of both the ESA and Met. Office winds have at the time of writing (mid-July 1992) remained the same. One month's data is considered sufficient to enable the basic characteristics of the data to be described adequately.

Flags are set by ESA and by the Met. Office for each wind observation to indicate whether various features are present which may affect the quality of the product eg whether only two rather than all three beams are functioning. Where it has been found that a particular flag has been set is associated with a poorer than average observation (in a statistical sense) all observations with the flag set have been excluded from the analysis below. For March, 3.7% of observations were thus excluded. Such observations would also be excluded from a model assimilation.

ESA reports with speeds below 4 m per s have been set to missing at source because of the belief that the method of retrieving speeds when the speed is light is invalid. However the Met. Office approach has been to retain the speed and direction and set a flag in the product confidence word. When comparing ESA and Met. Office winds, Met. Office winds below 4 m per s have therefore been excluded in order to obtain a true comparison.

To enable a comparison to be made between the satellite derived winds and conventional observations, ship data from the Observation Processing Database (OPD) have been extracted for March 1992. Not all ship data have been used since it is known that a significant proportion of the ship observations are of poor quality. To select the `best' ships, the RMS (O-B) vector wind has been calculated for each 10 x 10 degree latitude/longitude box for March using all ships (but excluding reports where the RMS vector difference > 25 m per s). Next, for each ship identifier, the mean over all observations of the ratios of the RMS vector difference to the appropriate box vector difference has been determined. Those ships with the mean ratio less than or equal to 1.0 and with more than 20 reports for the month are considered to be the most `reliable' ships and these have been used in the comparison with ERS-1 winds. The number of observations thus produced forms 22% of the total number.

3. Results

In this section the abbreviation ESA will be used for the ESA derived ERS-1 winds, MO for the Met. Office winds and SHIP for the reliable ships. For all results, observations where the RMS (O-B) vector wind difference exceeds 25 m per s are excluded.

3.1 Histograms

Figures 2 to 13 show histograms for ESA and MO O-B speed and direction differences categorised according to the mean of the ESA, MO and background speed. Note that there are no observation speeds below 4 m per s included for the reason stated in section 2. Since the program producing the statistics is expensive to run using all the data, one tenth of the data, randomly chosen using a pseudo-random number generator, has been used here. If one assumes the background field is in general a reasonable approximation to the `truth', the figures show :

- for wind speeds, the ESA and MO winds are of similar quality

- for wind directions, the MO winds are far superior, principally because the ESA winds are frequently about 180 degrees in error (even at high speeds)

- the wind directions for ESA and MO winds are in better agreement with the background direction for the higher speeds.(Note that at low speeds the background direction itself has greater error).

It is known that ESA are addressing the `de-aliasing' problem (selection of the correct solution from the four possibilities) and an improved algorithm is expected to be introduced soon.

3.2 Tables

Table 1 shows various statistics for the ESA and MO winds. Results have been broken down by latitude band. Note again that all MO winds below 4 m per s are excluded to allow a more genuine comparison with the ESA winds. It is clear that for all latitude bands the MO winds are closer to the background field (and hence assumed to be superior) than the ESA winds. This is more particularly evident for the directional statistics, due to selection of many ESA wind solutions which are 180 degrees out.

The design criterion for the ERS-1 winds - for winds between 4-20 m per s - is a RMS difference from `truth' of 2.0 m per s for speeds and 20 degrees for directions. The global results for MO winds of 2.4 m per s and 23.1 degrees respectively are therefore quite close to the design criterion and these O-B values include background field errors and errors due to differences between observation and model in resolution and in time (representativeness errors).

Table 2 shows the same statistics as table 1 for the MO and SHIP winds. In this case MO winds of all speeds are included. Here we see that the MO winds have smaller absolute biases and smaller SD differences than the SHIPs. The mean speeds and mean biases are about 2 m per s greater for the SHIPs than for the MO winds. This may reflect a positive bias in the SHIP winds. Possible reasons for this in the case of instrument measurement may be due to the anemometers in general recording a speed which is representative of a wind above 10 m height or in the case of visual estimation to too much weight being given to gusts. The negative O-B speed bias for MO winds may well be due to a negative bias in the observations but could also be due to a positive bias in the model speeds (caused in part by a positive bias in the SHIP winds which are used by the model).

In table 3, statistics for MO and SHIP winds are displayed for different speed categories. Except for mean O-B speeds in the 0-5 m per s band, where the SHIPs give a smaller absolute value, the quantities for MO winds are all better than equivalent SHIP values.

Table 4 shows results categorised by the midbeam angle of incidence for MO winds. This angle of incidence is a measure of the position of the report in the swathe (small angles are equivalent to the inner edge of swathe). We note that reports on the inner edge tend to have larger mean and SD direction differences and hence RMS vector differences than other reports. The cause of this is not known but may well be due to the physics of the system rather than the retrieval scheme. From August 1992 it is intended to exclude observations from any assimilation runs that have the midbeam angle of incidence less than or equal to 20 degrees - equivalent to the two innermost observations in the swathe.

3.3 Box statistics

Figures 14-17 show, for 10 x 10 degree latitude/longitude boxes, numbers of observations, mean vector winds, mean (O-B) vector winds and RMS (O-B) vector difference, for MO winds. Figures 18-21 display the same information for SHIPs.

Fig 14 shows the large spatial variation in the number of observations. (A `K' represents thousands). For example, only 27 observations were present in the North Sea but over 10000 in several boxes in the west Atlantic. The mean vector wind arrows (fig 15) display well-established features such as the Azores High and Trade Winds. The (O-B) vector wind arrows (fig 16) are generally in the opposite direction to the mean vector winds, reflecting the fact that mean observation speeds are lighter than the background. The RMS (O-B) vector wind differences in fig 17 range from about 2 m per s in some areas of the Tropics to 5-9 m per s near Antarctica.

Fig 18 for SHIPs highlights the fact that numbers of ship observations are small compared to ERS-1 numbers, particularly in the southern hemisphere. (The same is true even if all ships had been used). The mean vector winds (fig 19), where comparisons are possible with those derived from MO winds (fig 15), are similar, as hoped for. (The scale of the arrow lengths in figs. 19 and 20 are the same as used for the ERS-1 winds in figs. 15 and 16). However the direction of the mean O-B winds in fig 20 is generally opposite to those of the MO winds, a consequence of the mean speed differences being of opposite sign. RMS vector speed differences (fig 21) are larger than for MO winds everywhere.

4. Summary

The results presented in this Note show that Met. Office derived winds from the ERS-1 scatterometer radar are of good quality and superior to even the most reliable ship observations. The ESA derived winds from the same instrument are of significantly poorer quality principally because the wind directons are frequently about 180 deg out.

The Met. Office winds are already proving beneficial to CFO in locating precisely the positions of various meteorological features and in some cases identifying features not apparent from the model surface wind field. As mentioned in the introduction, it is unfortunate that winds are often not available around the UK because of the operation of the SAR instrument. Requests have been made to ESA to try to reduce the frequency of this occurrence.

Various experiments have been conducted in S Division to determine their impact on the operational model's assimilation and forecast, with a view to assimilating them routinely. The conclusion so far is that the impact is generally small; however this may reflect inadequacies in the assimilation of these very high density observations and the relatively high quality of the background surface wind field rather than any problems with the observations.

Of some concern from an operational point of view is that even as late as July 1992 there are niggling problems with either the production of the data at source or their transmission. This has resulted in a loss of data for several hours and occasionally for several days. In an NWP environment this is clearly not a satisfatory situation.

FROM 13/11:22Z TO 13/11:24Z
ERS1 10M WINDS UK AREA

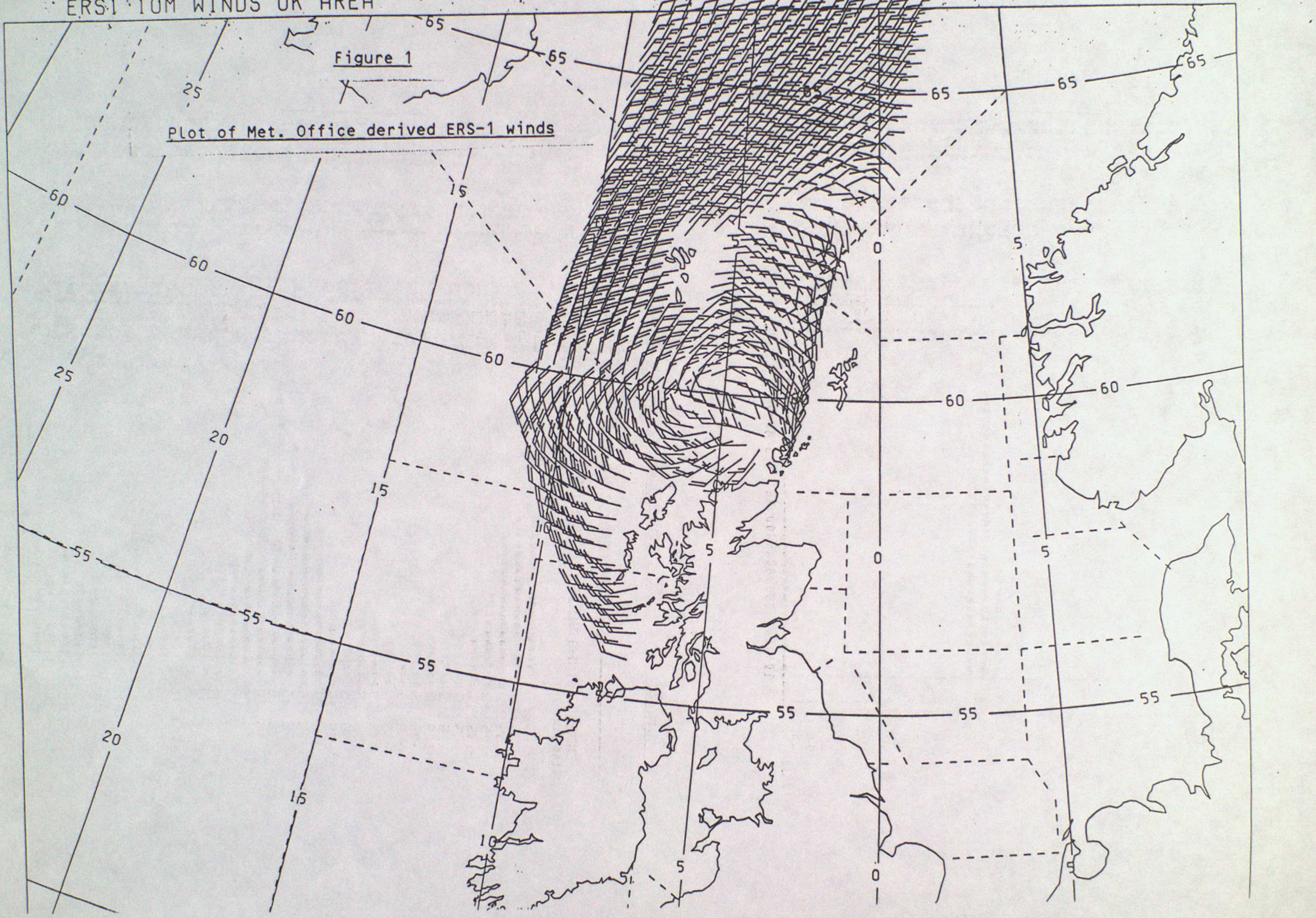


Figure 1

Plot of Met. Office derived ERS-1 winds

Figure 2 Histogram of ESA O-B speeds : mean speeds < 5 m/s

---------------------- (ESA O+B)/2 SPEED=0 TO 5 M/S ----------------------

ESA O-B WIND SPEED

EMBS Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-13	0	0	0.00	0.00
-12	0	0	0.00	0.00
-11	0	0	0.00	0.00
-10	0	0	0.00	0.00
-9	0	0	0.00	0.00
-8	0	0	0.00	0.00
-7	0	0	0.00	0.00
-6	0	0	0.00	0.00
-5	0	0	0.00	0.00
-4	0	0	0.00	0.00
-3	0	0	0.00	0.00
-2	0	0	0.00	0.00
-1	279	279	15.87	15.87
0	843	1122	47.95	63.82
1	628	1750	35.72	99.54
2	8	1758	0.46	100.00
3	0	1758	0.00	100.00
4	0	1758	0.00	100.00
5	0	1758	0.00	100.00
6	0	1758	0.00	100.00
7	0	1758	0.00	100.00
8	0	1758	0.00	100.00
9	0	1758	0.00	100.00
10	0	1758	0.00	100.00
11	0	1758	0.00	100.00
12	0	1758	0.00	100.00
13	0	1758	0.00	100.00

100 200 300 400 500 600 700 800

Frequency

Figure 3 Histogram of ESA O-B directions : mean speeds < 5 m/s

--------------------- (ESA O+B)/2 SPEED=0 TO 5 M/S ---------------------

ESA O-B WIND DIRECTION

EMBD Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-175	83	83	4.72	4.72
-165	85	168	4.84	9.56
-155	73	241	4.15	13.71
-145	41	282	2.33	16.04
-135	31	313	1.76	17.80
-125	14	327	0.80	18.60
-115	10	337	0.57	19.17
-105	13	350	0.74	19.91
-95	9	359	0.51	20.42
-85	13	372	0.74	21.16
-75	12	384	0.68	21.84
-65	26	410	1.48	23.32
-55	31	441	1.76	25.09
-45	29	470	1.65	26.73
-35	37	507	2.10	28.84
-25	73	580	4.15	32.99
-15	102	682	5.80	38.79
-5	118	800	6.71	45.51
5	160	960	9.10	54.61
15	126	1086	7.17	61.77
25	97	1183	5.52	67.29
35	62	1245	3.53	70.82
45	65	1310	3.70	74.52
55	27	1337	1.54	76.05
65	31	1368	1.76	77.82
75	9	1377	0.51	78.33
85	11	1388	0.63	78.95
95	9	1397	0.51	79.47
105	9	1406	0.51	79.98
115	18	1424	1.02	81.00
125	17	1441	0.97	81.97
135	36	1477	2.05	84.02
145	39	1516	2.22	86.23
155	58	1574	3.30	89.53
165	73	1647	4.15	93.69
175	111	1758	6.31	100.00

20 40 60 80 100 120 140 160

Frequency

Figure 4 Histogram of MO O-B speeds : mean speeds < 5 m/s

------------------ (UKMO O+B)/2 SPEED=0 TO 5 M/S ------------------

UKMO O-B WIND SPEED

OMBS Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-13	0	0	0.00	0.00
-12	0	0	0.00	0.00
-11	0	0	0.00	0.00
-10	0	0	0.00	0.00
-9	0	0	0.00	0.00
-8	0	0	0.00	0.00
-7	0	0	0.00	0.00
-6	0	0	0.00	0.00
-5	0	0	0.00	0.00
-4	0	0	0.00	0.00
-3	0	0	0.00	0.00
-2	0	0	0.00	0.00
-1	161	161	15.48	15.48
0	379	540	36.44	51.92
1	496	1036	47.69	99.62
2	4	1040	0.38	100.00
3	0	1040	0.00	100.00
4	0	1040	0.00	100.00
5	0	1040	0.00	100.00
6	0	1040	0.00	100.00
7	0	1040	0.00	100.00
8	0	1040	0.00	100.00
9	0	1040	0.00	100.00
10	0	1040	0.00	100.00
11	0	1040	0.00	100.00
12	0	1040	0.00	100.00
13	0	1040	0.00	100.00

100 200 300 400 500

Frequency

Figure 5 Histogram of MO O-B directions : mean speeds < 5 m/s

------------------ (UKMO O+B)/2 SPEED=0 TO 5 M/S ------------------

UKMO O-B WIND DIRECTION

OMBD Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-175	0	0	0.00	0.00
-165	1	1	0.10	0.10
-155	0	1	0.00	0.10
-145	0	1	0.00	0.10
-135	0	1	0.00	0.10
-125	0	1	0.00	0.10
-115	1	2	0.10	0.19
-105	1	3	0.10	0.29
-95	3	6	0.29	0.58
-85	9	15	0.87	1.44
-75	5	20	0.48	1.92
-65	11	31	1.06	2.98
-55	14	45	1.35	4.33
-45	19	64	1.83	6.15
-35	37	101	3.56	9.71
-25	70	171	6.73	16.44
-15	116	287	11.15	27.60
-5	186	473	17.88	45.48
5	218	691	20.96	66.44
15	163	854	15.67	82.12
25	78	932	7.50	89.62
35	38	970	3.65	93.27
45	25	995	2.40	95.67
55	12	1007	1.15	96.83
65	10	1017	0.96	97.79
75	10	1027	0.96	98.75
85	7	1034	0.67	99.42
95	3	1037	0.29	99.71
105	2	1039	0.19	99.90
115	0	1039	0.00	99.90
125	0	1039	0.00	99.90
135	0	1039	0.00	99.90
145	1	1040	0.10	100.00
155	0	1040	0.00	100.00
165	0	1040	0.00	100.00
175	0	1040	0.00	100.00

30 60 90 120 150 180 210

Frequency

Figure_6   Histogram_of_ESA_O-B_speeds : mean speeds 5-15 m/s

------------------------ (ESA O+B)/2 SPEED=5 TO 15 M/S ------------------------

ESA O-B WIND SPEED

EMBS Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-13	18	18	0.01	0.01
-12	14	32	0.01	0.02
-11	58	90	0.04	0.06
-10	123	213	0.08	0.13
-9	323	536	0.20	0.33
-8	734	1270	0.46	0.79
-7	1511	2781	0.94	1.73
-6	3571	6352	2.23	3.96
-5	7338	13690	4.58	8.54
-4	13650	27340	8.51	17.05
-3	22195	49535	13.84	30.90
-2	28897	78432	18.03	48.92
-1	28337	106769	17.68	66.60
0	22100	128869	13.79	80.39
1	13893	142762	8.67	89.05
2	8056	150818	5.03	94.08
3	4041	154859	2.52	96.60
4	2249	157108	1.40	98.00
5	1222	158330	0.76	98.76
6	758	159088	0.47	99.24
7	488	159576	0.30	99.54
8	279	159855	0.17	99.71
9	171	160026	0.11	99.82
10	114	160140	0.07	99.89
11	64	160204	0.04	99.93
12	34	160238	0.02	99.95
13	74	160312	0.05	100.00

6000   12000   18000   24000

Frequency

Figure 7   Histogram of ESA O-B directions : mean speeds 5-15 m/s

------------------------ (ESA O+B)/2 SPEED=5 TO 15 M/S ------------------------

ESA O-B WIND DIRECTION

EMBD Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-175	10279	10279	6.41	6.41
-165	10466	20745	6.53	12.94
-155	7615	28360	4.75	17.69
-145	4220	32580	2.63	20.32
-135	1929	34509	1.20	21.53
-125	855	35364	0.53	22.06
-115	543	35907	0.34	22.40
-105	406	36313	0.25	22.65
-95	331	36644	0.21	22.86
-85	324	36968	0.20	23.06
-75	425	37393	0.27	23.33
-65	501	37894	0.31	23.64
-55	812	38706	0.51	24.14
-45	1507	40213	0.94	25.08
-35	3040	43253	1.90	26.98
-25	6155	49408	3.84	30.82
-15	10970	60378	6.84	37.66
-5	15959	76337	9.95	47.62
5	17529	93866	10.93	58.55
15	13581	107447	8.47	67.02
25	8578	116025	5.35	72.37
35	4487	120512	2.80	75.17
45	2099	122611	1.31	76.48
55	1095	123706	0.68	77.17
65	613	124319	0.38	77.55
75	397	124716	0.25	77.80
85	346	125062	0.22	78.01
95	306	125368	0.19	78.20
105	356	125724	0.22	78.42
115	496	126220	0.31	78.73
125	712	126932	0.44	79.18
135	1603	128535	1.00	80.18
145	3386	131921	2.11	82.29
155	6505	138426	4.06	86.35
165	9610	148036	5.99	92.34
175	12276	160312	7.66	100.00

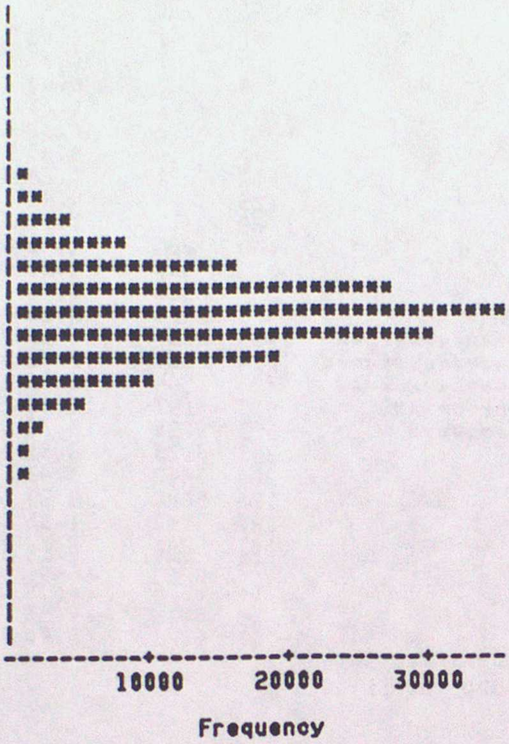
4000   8000   12000   16000

Frequency

Figure 8 Histogram of MO O-B speeds : mean speeds 5-15 m/s

------------------------ (UKMO O+B)/2 SPEED=5 TO 15 M/S ------------------------

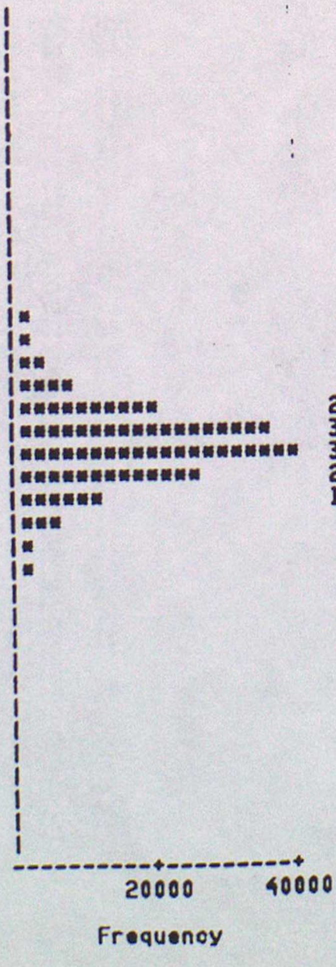
UKMO O-B WIND SPEED



OMBS Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-13	7	7	0.00	0.00
-12	15	22	0.01	0.01
-11	20	42	0.01	0.03
-10	43	85	0.03	0.05
-9	157	242	0.10	0.15
-8	310	552	0.19	0.34
-7	742	1294	0.46	0.80
-6	1533	2827	0.95	1.75
-5	3779	6606	2.34	4.10
-4	8091	14697	5.02	9.11
-3	15793	30490	9.79	18.90
-2	27006	57496	16.74	35.64
-1	34753	92249	21.54	57.19
0	29702	121951	18.41	75.60
1	18578	140529	11.52	87.12
2	10073	150602	6.24	93.36
3	5005	155607	3.10	96.47
4	2443	158050	1.51	97.98
5	1380	159430	0.86	98.84
6	758	160188	0.47	99.31
7	472	160660	0.29	99.60
8	296	160956	0.18	99.78
9	160	161116	0.10	99.88
10	87	161203	0.05	99.94
11	46	161249	0.03	99.96
12	24	161273	0.01	99.98
13	34	161307	0.02	100.00

Figure 9 Histogram of MO O-B directions : mean speeds 5-15 m/s

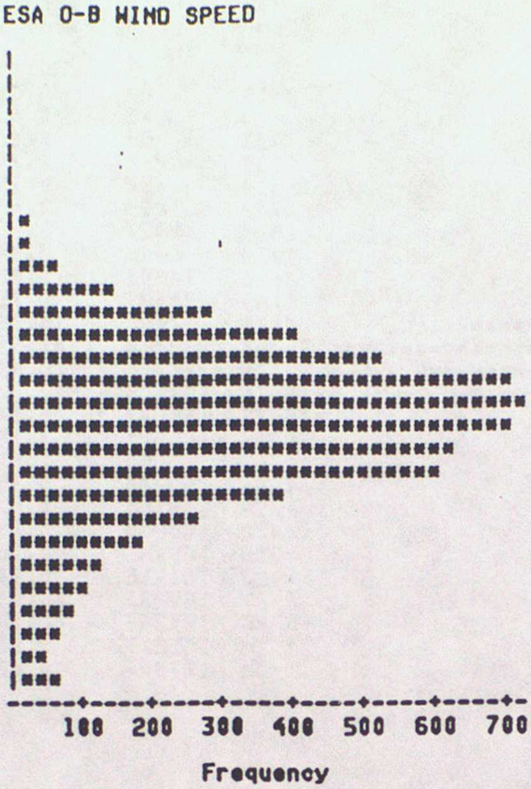
----------------- (UKMO O+B)/2 SPEED=5 TO 15 M/S ---------------



OMBD Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-175	3	3	0.00	0.00
-165	1	4	0.00	0.00
-155	4	8	0.00	0.00
-145	11	19	0.01	0.01
-135	10	29	0.01	0.02
-125	16	45	0.01	0.03
-115	40	85	0.02	0.05
-105	81	166	0.05	0.10
-95	157	323	0.10	0.20
-85	283	606	0.18	0.38
-75	435	1041	0.27	0.65
-65	638	1679	0.40	1.04
-55	1047	2726	0.65	1.69
-45	1673	4399	1.04	2.73
-35	3631	8030	2.25	4.98
-25	8734	16764	5.41	10.39
-15	20549	37313	12.74	23.13
-5	35858	73171	22.23	45.36
5	39374	112545	24.41	69.77
15	26020	138565	16.13	85.90
25	12205	150770	7.57	93.47
35	5050	155820	3.13	96.60
45	2286	158106	1.42	98.02
55	1284	159390	0.80	98.81
65	757	160147	0.47	99.28
75	447	160594	0.28	99.56
85	327	160921	0.20	99.76
95	177	161098	0.11	99.87
105	88	161186	0.05	99.92
115	49	161235	0.03	99.96
125	22	161257	0.01	99.97
135	21	161278	0.01	99.98
145	12	161290	0.01	99.99
155	9	161299	0.01	100.00
165	7	161306	0.00	100.00
175	1	161307	0.00	100.00

Figure 10   Histogram of ESA O-B speeds : mean speeds > 15 m/s

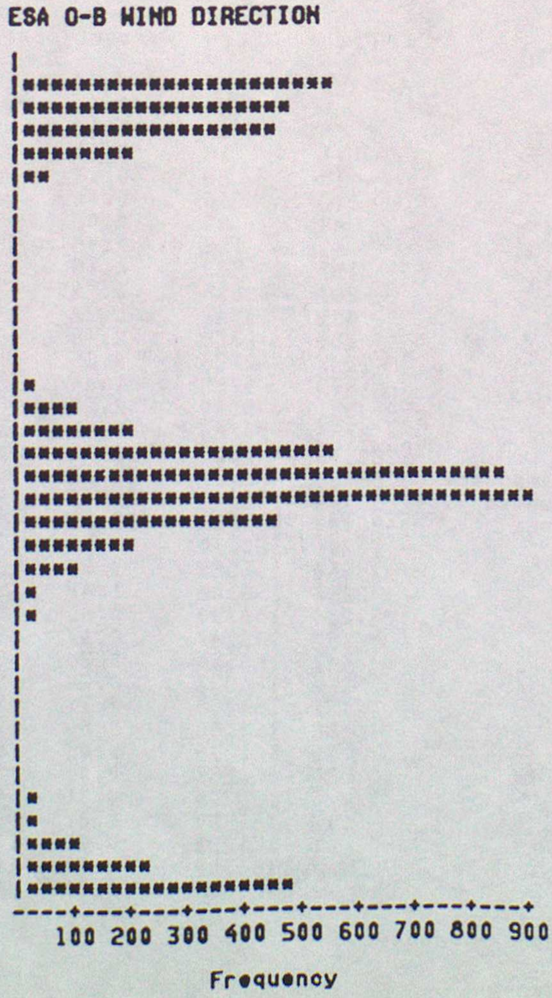
------------------------ (ESA O+B)/2 SPEED=>= 15 M/S ------------------------



EMBS Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-13	1	1	0.02	0.02
-12	0	1	0.00	0.02
-11	0	1	0.00	0.02
-10	0	1	0.00	0.02
-9	1	2	0.02	0.03
-8	2	4	0.03	0.07
-7	17	21	0.28	0.35
-6	25	46	0.41	0.76
-5	66	112	1.09	1.84
-4	146	258	2.40	4.25
-3	279	537	4.59	8.84
-2	391	928	6.44	15.28
-1	526	1454	8.66	23.94
0	703	2157	11.58	35.52
1	724	2881	11.92	47.44
2	703	3584	11.58	59.02
3	613	4197	10.09	69.11
4	593	4790	9.76	78.87
5	383	5173	6.31	85.18
6	269	5442	4.43	89.61
7	178	5620	2.93	92.54
8	120	5740	1.98	94.52
9	107	5847	1.76	96.28
10	77	5924	1.27	97.55
11	54	5978	0.89	98.44
12	34	6012	0.56	99.00
13	61	6073	1.00	100.00

Figure 11   Histogram of ESA O-B directions : mean speeds > 15 m/s

------------------------ (ESA O+B)/2 SPEED=>= 15 M/S ------------------------



EMBD Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-175	549	549	9.04	9.04
-165	480	1029	7.90	16.94
-155	441	1470	7.26	24.21
-145	189	1659	3.11	27.32
-135	51	1710	0.84	28.16
-125	10	1720	0.16	28.32
-115	6	1726	0.10	28.42
-105	2	1728	0.03	28.45
-95	1	1729	0.02	28.47
-85	1	1730	0.02	28.49
-75	1	1731	0.02	28.50
-65	7	1738	0.12	28.62
-55	11	1749	0.18	28.80
-45	36	1785	0.59	29.39
-35	90	1875	1.48	30.87
-25	208	2083	3.42	34.30
-15	558	2641	9.19	43.49
-5	858	3499	14.13	57.62
5	908	4407	14.95	72.57
15	455	4862	7.49	80.06
25	204	5066	3.36	83.42
35	89	5155	1.47	84.88
45	17	5172	0.28	85.16
55	13	5185	0.21	85.38
65	6	5191	0.10	85.48
75	7	5198	0.12	85.59
85	10	5208	0.16	85.76
95	11	5219	0.18	85.94
105	4	5223	0.07	86.00
115	4	5227	0.07	86.07
125	3	5230	0.05	86.12
135	14	5244	0.23	86.35
145	33	5277	0.54	86.89
155	98	5375	1.61	88.51
165	228	5603	3.75	92.26
175	470	6073	7.74	100.00

Figure 12 Histogram of MO O-B speeds : mean speeds > 15 m/s

------------------------- (UKMO O+B)/2 SPEED=>= 15 M/S -----------------------

UKMO O-B WIND SPEED

OMBS Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-13	1	1	0.02	0.02
-12	0	1	0.00	0.02
-11	0	1	0.00	0.02
-10	0	1	0.00	0.02
-9	0	1	0.00	0.02
-8	4	5	0.07	0.09
-7	9	14	0.16	0.24
-6	22	36	0.38	0.62
-5	68	104	1.17	1.79
-4	167	271	2.88	4.68
-3	299	570	5.16	9.83
-2	495	1065	8.54	18.37
-1	683	1748	11.78	30.16
0	938	2686	16.18	46.34
1	821	3507	14.16	60.51
2	773	4280	13.34	73.84
3	565	4845	9.75	83.59
4	367	5212	6.33	89.92
5	210	5422	3.62	93.55
6	131	5553	2.26	95.81
7	82	5635	1.41	97.22
8	56	5691	0.97	98.19
9	39	5730	0.67	98.86
10	25	5755	0.43	99.29
11	13	5768	0.22	99.52
12	7	5775	0.12	99.64
13	21	5796	0.36	100.00

100 200 300 400 500 600 700 800 900

Frequency

Figure 13 Histogram of MO O-B directions : mean speeds > 15 m/s

------------------------- (UKMO O+B)/2 SPEED=>= 15 M/S -----------------------

UKMO O-B WIND DIRECTION

OMBD Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
-175	0	0	0.00	0.00
-165	0	0	0.00	0.00
-155	0	0	0.00	0.00
-145	0	0	0.00	0.00
-135	0	0	0.00	0.00
-125	0	0	0.00	0.00
-115	0	0	0.00	0.00
-105	0	0	0.00	0.00
-95	1	1	0.02	0.02
-85	0	1	0.00	0.02
-75	7	8	0.12	0.14
-65	7	15	0.12	0.26
-55	19	34	0.33	0.59
-45	34	68	0.59	1.17
-35	87	155	1.50	2.67
-25	224	379	3.86	6.54
-15	751	1130	12.96	19.50
-5	1382	2512	23.84	43.34
5	1745	4257	30.11	73.45
15	1031	5288	17.79	91.24
25	349	5637	6.02	97.26
35	117	5754	2.02	99.28
45	21	5775	0.36	99.64
55	17	5792	0.29	99.93
65	1	5793	0.02	99.95
75	2	5795	0.03	99.98
85	1	5796	0.02	100.00
95	0	5796	0.00	100.00
105	0	5796	0.00	100.00
115	0	5796	0.00	100.00
125	0	5796	0.00	100.00
135	0	5796	0.00	100.00
145	0	5796	0.00	100.00
155	0	5796	0.00	100.00
165	0	5796	0.00	100.00
175	0	5796	0.00	100.00

400 800 1200 1600

Frequency

figure 14

UKMO WINDS

NUMBER OF OBS WITHIN TOLERANCE

MARCH 1992

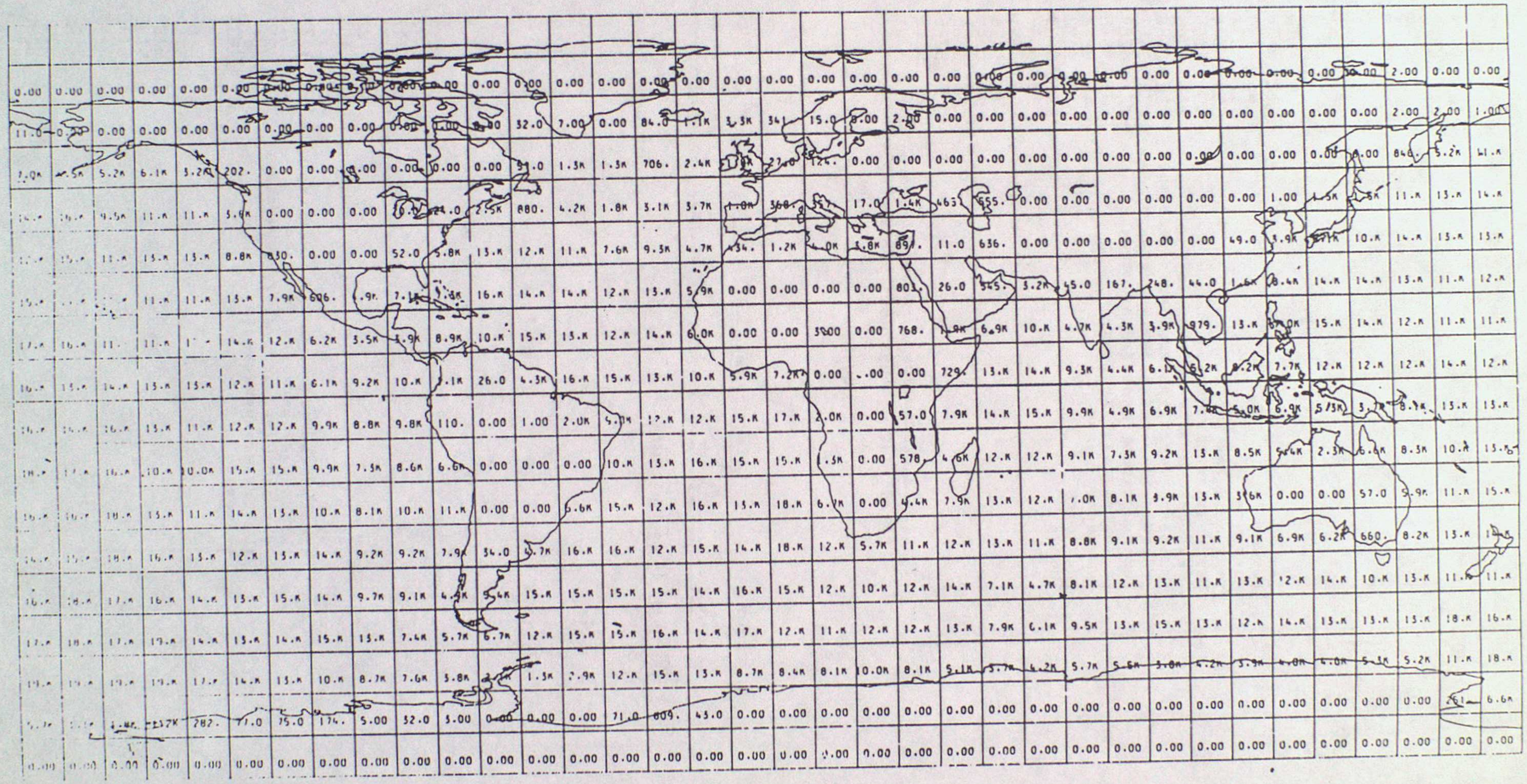
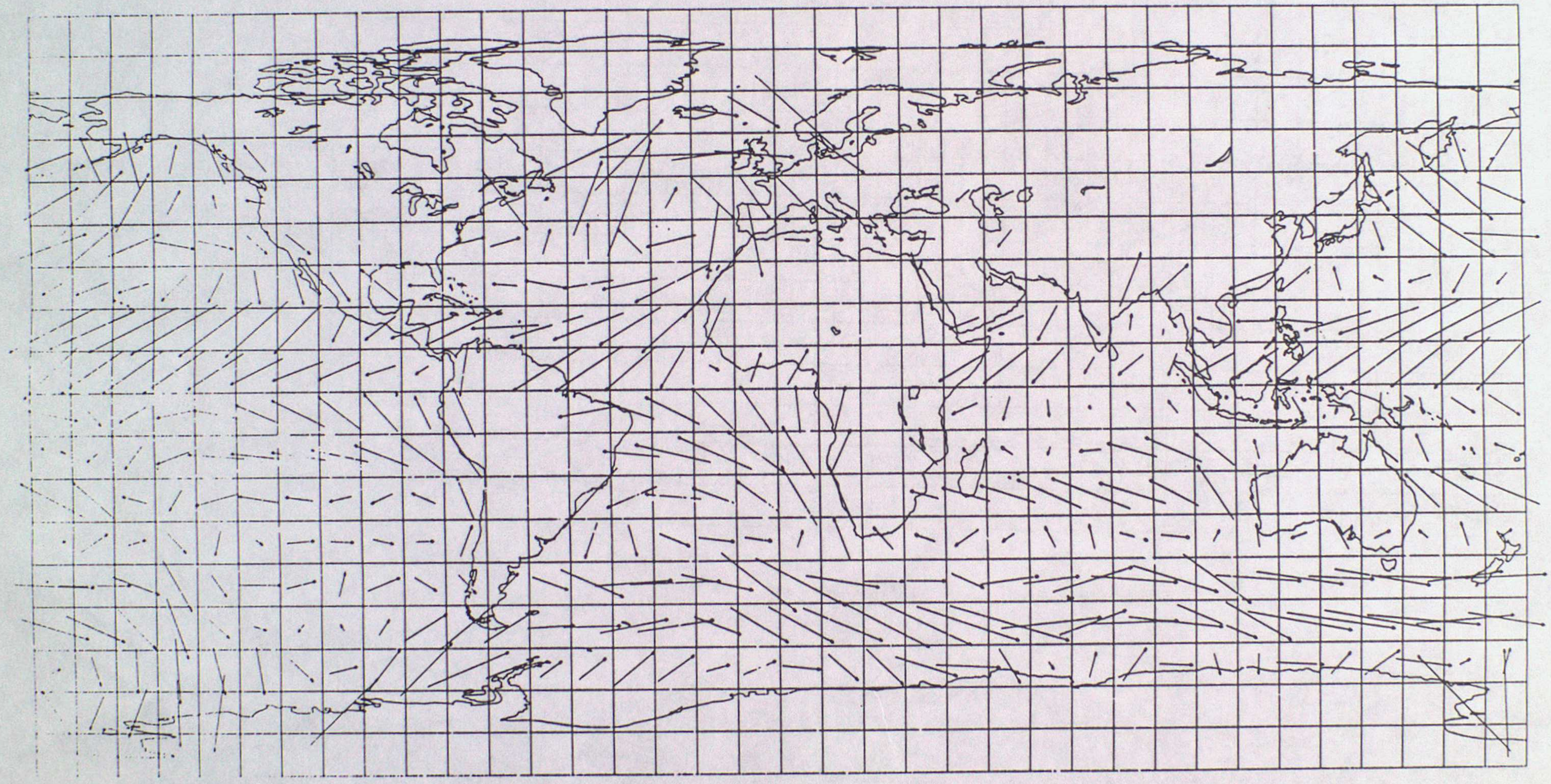


Figure 15

UKMO WINDS

MEAN VECTOR WIND

MARCH 1992



10M/S ARROW

Figure 16

UKMO WINDS

MEAN O-B VECTOR WIND

MARCH 1992

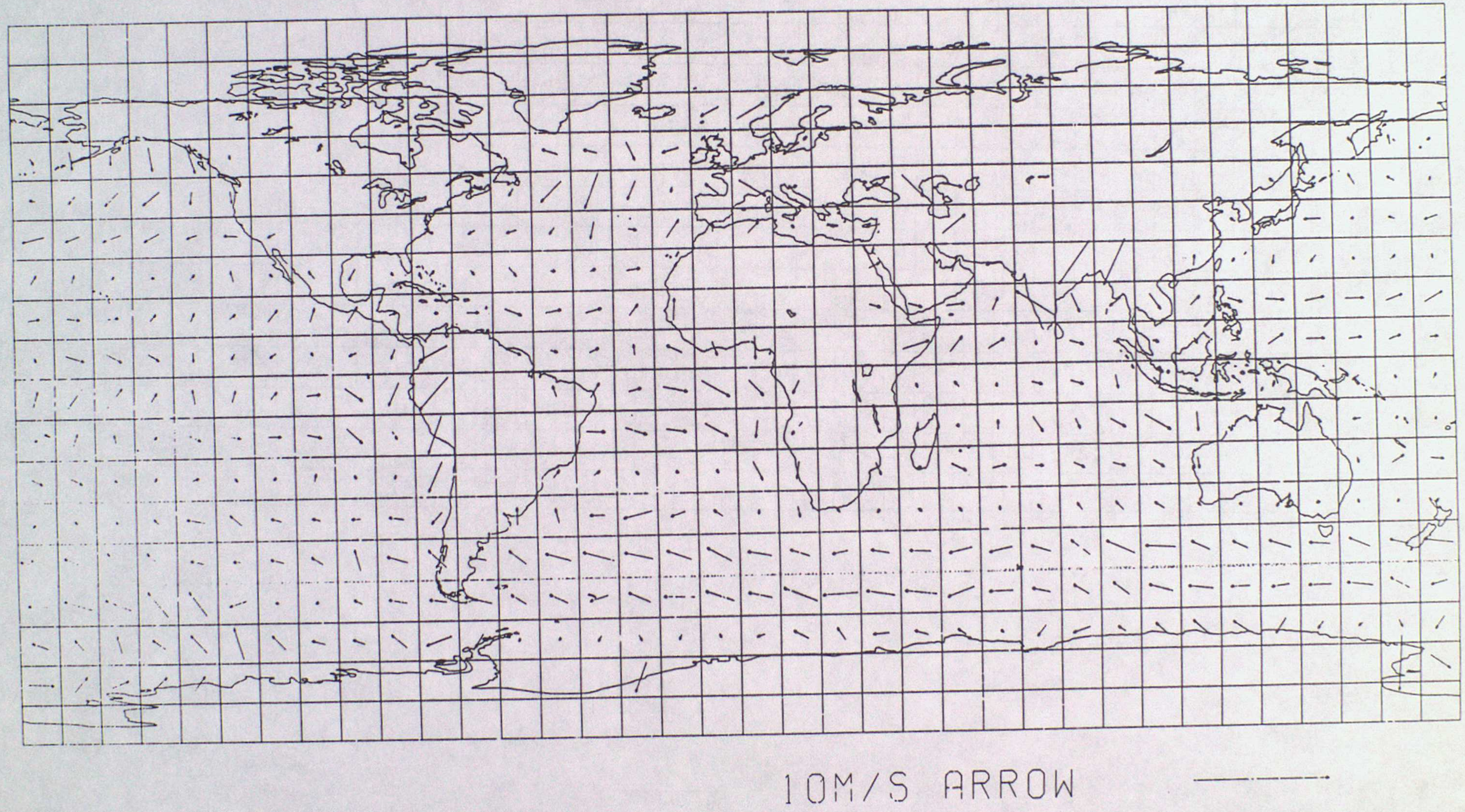


Figure 17

UKMO WINDS
RMS O-B VECTOR DIFFERENCE
MARCH 1992

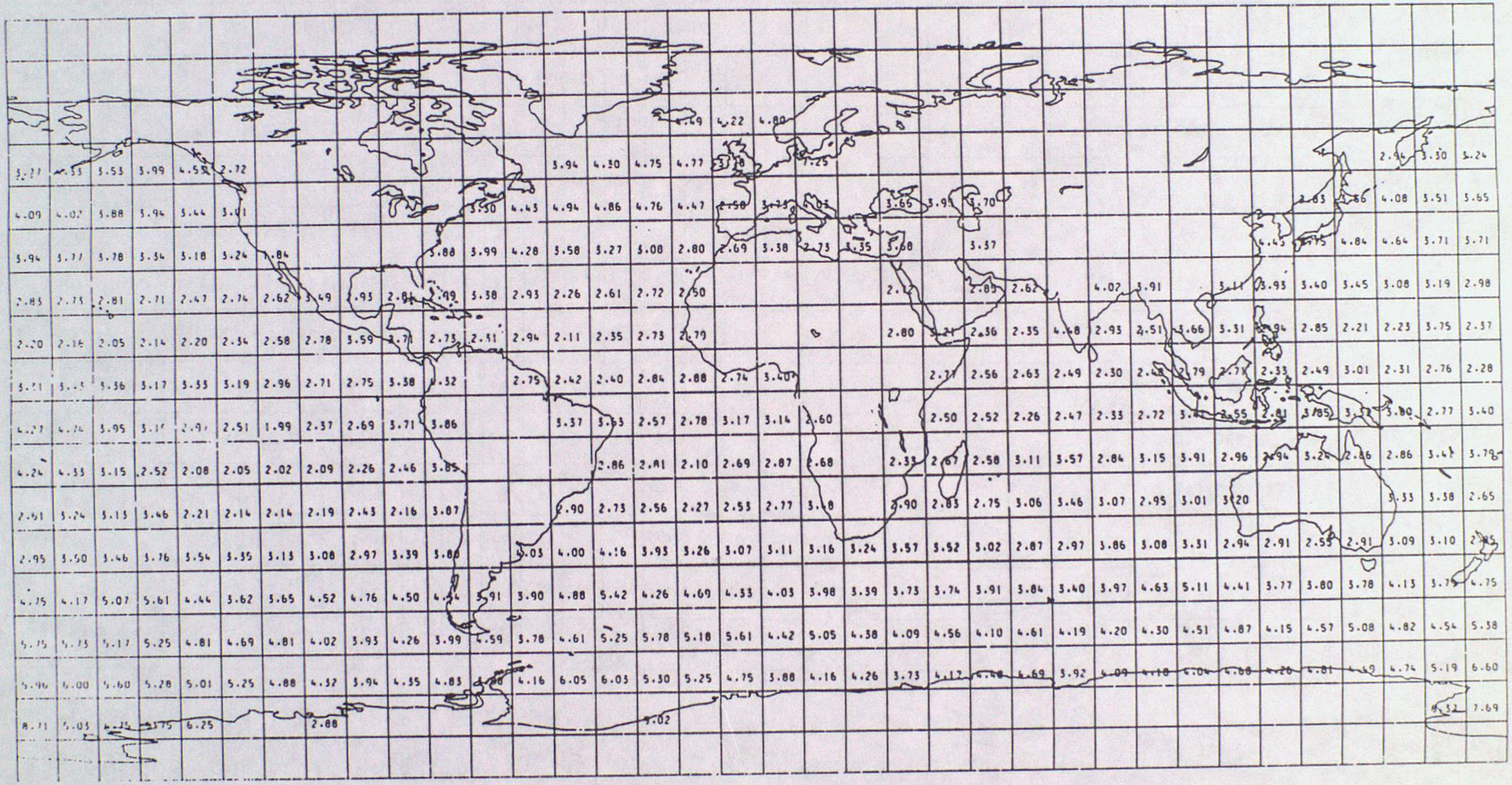


Figure 18

NUMBER OF OBSERVATIONS FOR RELIABLE SHIPS
MARCH 1992
OBSERVATIONS WITH RMS(O-B) > 25 M PER S EXCLUDED

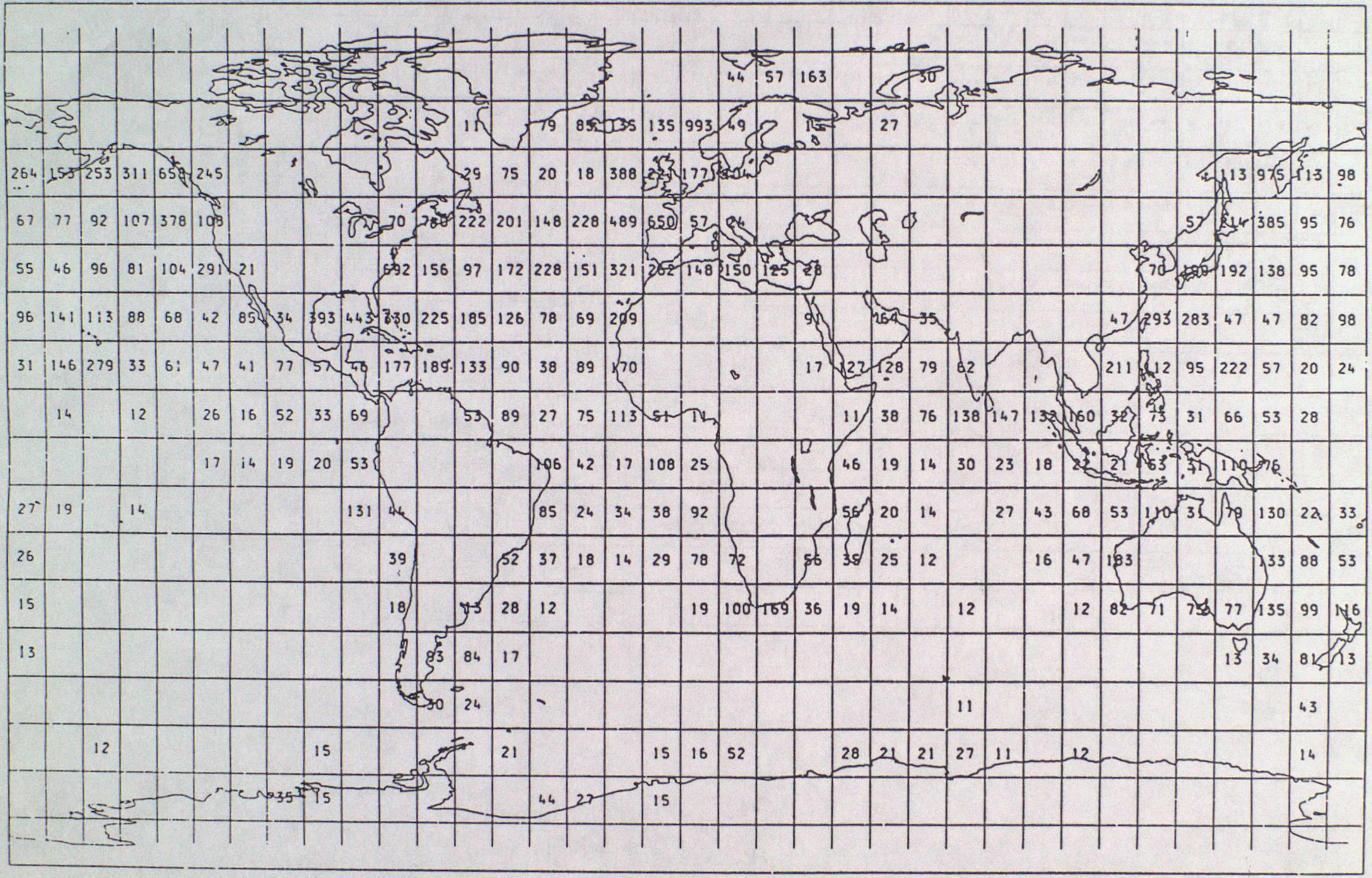


Figure 19

RELIABLE SHIPS : VECTOR MEAN WINDS
MARCH 1992
OBSERVATIONS WITH RMS(O-B) > 25 M PER S EXCLUDED
ARROWS ARE PRINTFD WHERE > 10 OBS ARE PRESENT

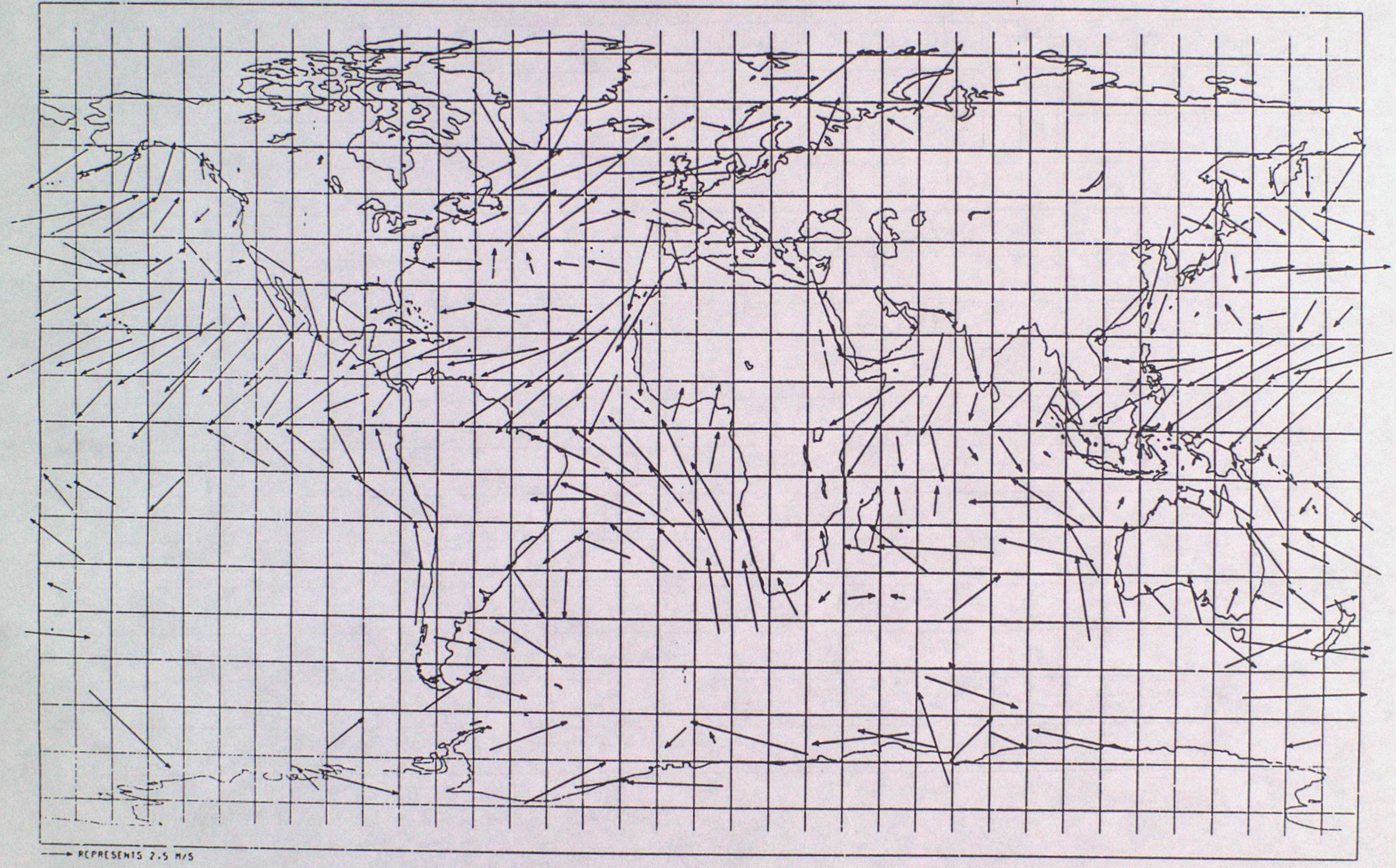
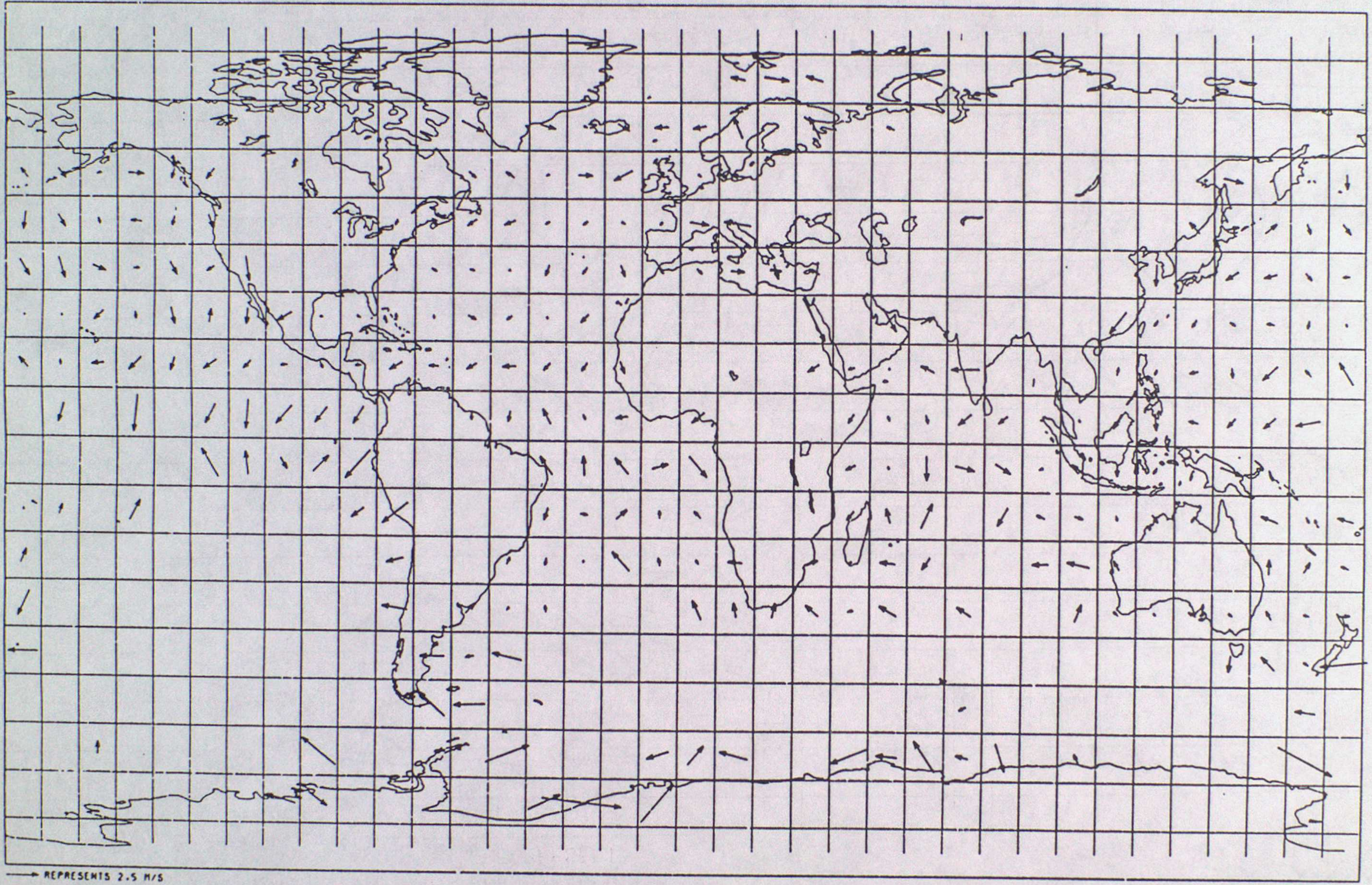


Figure 20

RELIABLE SHIPS : VECTOR MEAN O-B WINDS
MARCH 1992
OBSERVATIONS WITH RMS(O-B) > 25 M PER S EXCLUDED
ARROWS ARE PRINTED WHERE > 10 OBS ARE PRESENT



REPRESENTS 2.5 M/S

Figure 21

RELIABLE SHIPS : RMS O-B VECTOR DIFFERENCES (M/S)
MARCH 1992
OBSERVATIONS WITH RMS(O-B) > 25 M PER S EXCLUDED
VALUES ARE PRINTED WHERE > 10 OBS ARE PRESENT

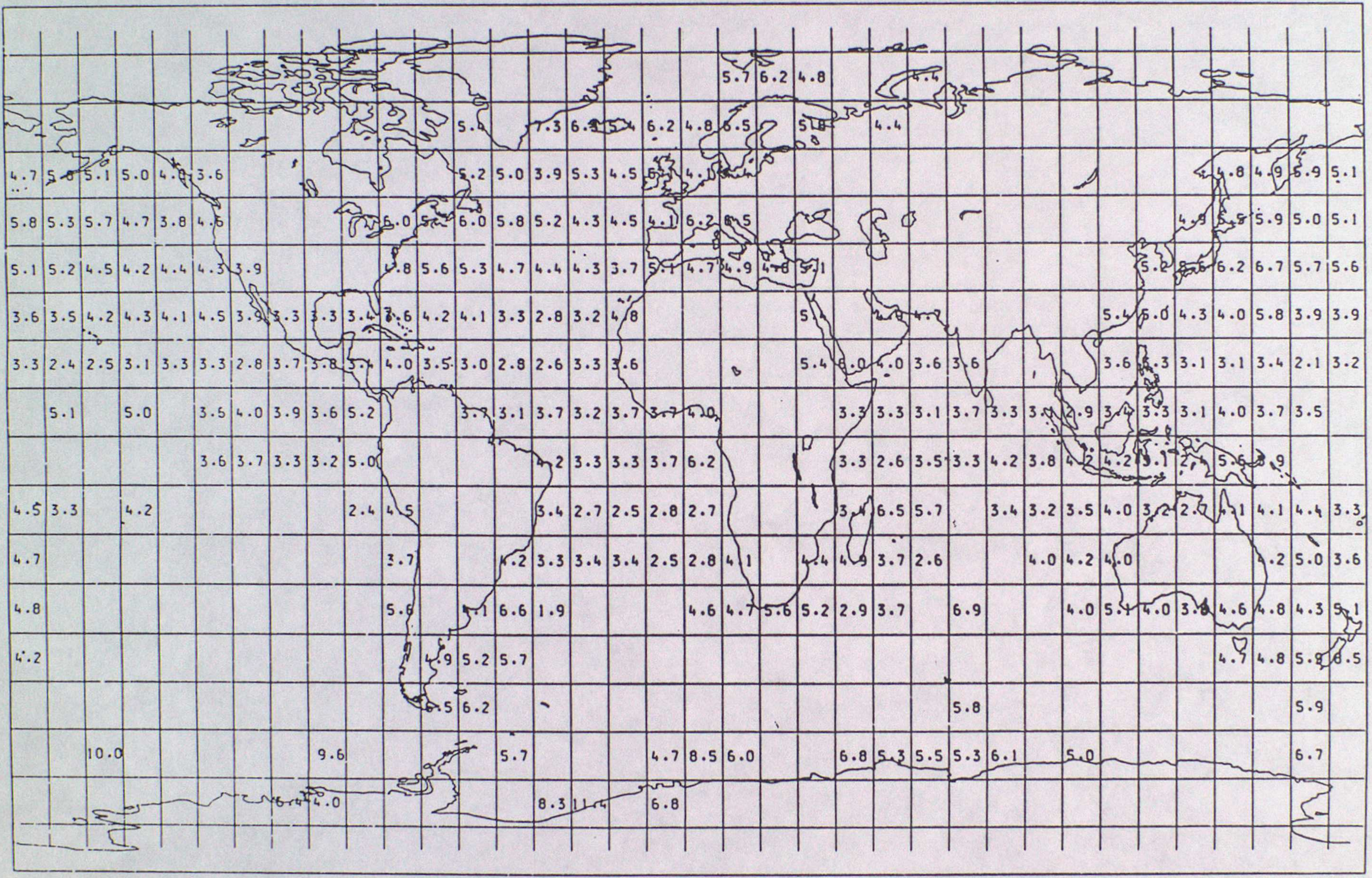


Table_1

Comparison_between_ESA_and_MO_winds

Breakdown_by_latitude_band

Units : speeds and vector winds in metres per second and directions in degrees

		Latitude band			
		30-90 deg S	30 S - 30 N	30-90 deg N	Global
No. of observations		800905	505873	187457	1494235
Mean obs. speed	ESA	8.5	6.7	8.6	7.7
	MO	8.9	7.1	9.1	8.2
Mean O-B speed	ESA	-1.2	-0.9	-1.1	-1.1
	MO	-0.6	-0.4	-0.5	-0.5
Mean O-B direction	ESA	-12.3	24.5	-2.2	1.1
	MO	2.5	-1.0	-1.1	0.9
SD O-B speed	ESA	3.1	2.1	2.6	2.7
	MO	2.8	1.8	2.3	2.4
SD O-B direction	ESA	101.8	109.3	100.7	105.0
	MO	25.5	19.0	21.2	23.1
RMS O-B speed	ESA	3.3	2.3	2.8	2.9
	MO	2.9	1.8	2.4	2.4
RMS O-B direction	ESA	102.5	112.0	100.7	105.0
	MO	25.6	19.0	21.2	23.1
RMS O-B vector	ESA	11.5	10.1	11.0	10.9
	MO	4.6	2.8	3.8	3.9

Table_2

Comparison_between_MO_and_SHIP_winds

Breakdown_by_latitude_band

Units : speeds and vector winds in metres per second and directions in degrees

		Latitude band			
		30-90 deg S	30 S - 30 N	30-90 deg N	Global
No. of observations	MO	917621	1104658	318917	2341186
	SHIP	2404	11611	16167	30182
Mean obs. speed	MO	7.8	4.5	6.7	6.1
	SHIP	8.8	6.5	9.0	8.0
Mean O-B speed	MO	-0.7	-0.7	-0.9	-0.7
	SHIP	1.5	0.9	1.2	1.1
Mean O-B direction	MO	0.9	-1.0	-2.6	-0.3
	SHIP	3.3	-0.8	-2.2	-1.2
SD O-B speed	MO	2.8	1.6	2.1	2.1
	SHIP	3.2	2.3	2.8	2.7
SD O-B direction	MO	28.9	24.4	23.1	25.1
	SHIP	41.8	33.4	34.0	34.5
RMS O-B speed	MO	2.9	1.7	2.3	2.2
	SHIP	3.5	2.5	3.0	2.9
RMS O-B direction	MO	28.9	24.4	23.2	25.1
	SHIP	41.9	33.4	34.1	34.5
RMS O-B vector	MO	4.5	2.6	3.5	3.6
	SHIP	5.6	3.8	4.9	4.6

Table 3

Comparison of MO and SHIP winds

Breakdown by mean speed

Units : speeds and vector winds in metres per second and directions in degrees

		Mean speed of observation and background					
		0-5	5-10	10-15	15-20	20-25	> 25
No. of obs	MO	869538	1124698	299385	45839	1726	0
	SHIP	7931	15918	5267	989	74	3
Mean obs speed	MO	3.2	6.4	11.8	16.9	22.8	
	SHIP	3.7	7.8	13.0	18.2	24.5	
Mean O-B speed	MO	-0.5	-1.0	-0.4	0.8	3.5	
	SHIP	0.2	1.1	1.9	3.2	6.2	
Mean O-B dirn.	MO	0.5	-0.7	0.6	-0.7	-2.8	
	SHIP	-0.2	-1.2	-2.0	-1.5	1.8	
SD O-B speed	MO	1.7	2.2	3.0	3.0	3.7	
	SHIP	2.1	2.5	3.1	3.5	3.3	
SD O-B dirn.	MO	38.2	25.0	19.0	15.3	13.2	
	SHIP	53.7	32.4	22.5	17.5	20.1	
RMS O-B vector	MO	2.7	3.7	4.8	5.3	7.0	
	SHIP	3.5	4.4	5.6	6.8	10.2	

Table 4

MO winds : Breakdown by midbeam angle of incidence

Units : speeds and vector winds in metres per second and directions in degrees

	Angle of incidence						
	15-20	20-25	25-30	30-35	35-40	40-45	45-50
No. of obs	123820	317314	370508	369796	492063	491084	122601
Mean obs speed	5.5	5.8	6.0	6.3	6.4	6.0	5.9
Mean O-B speed	-1.4	-1.1	-0.9	-0.6	-0.5	-0.7	-1.0
Mean O-B dirn.	-0.8	-0.7	-0.9	-0.7	-0.1	0.3	0.4
SD O-B speed	2.2	2.2	2.2	2.3	2.3	2.2	2.2
SD O-B dirn.	33.9	28.9	26.2	26.7	25.0	24.2	25.2
RMS O-B vector	4.2	3.8	3.6	3.7	3.5	3.4	3.6