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Day-to-Day Comparison Study of Seasat Scatterometer Winds with Winds Observed from Islands in the Tropical Pacific

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A Day-to-Day Comparison Study of Seasat Scatterometer Winds with Winds Observed from Islands in the Tropical Pacific

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ABSTRACT. The Seasat scatterometer observed near-surface vector winds over the world ocean from an 800-km orbit by measuring radar backscatter from the wind-roughened surface. The early end of the mission in 1978 forestalled some of the planned ground-truth validation experiments; questions remain about the instrument's performance, in particular away from mid-latitudes. To increase the geographical range of SASS and *in situ* comparison experiments, we have compared data from islands in the tropical Pacific and contemporaneous scatterometer winds. We used satellite winds derived from two different wind vector algorithms (the signal processing that reduces the radar backscatter to wind speed and direction). The SASS-2 algorithm due to Wentz provides clearly better agreement in wind speed than the earlier SASS-1 algorithm. SASS-1 speeds tend to be higher than the island measurements by about 1 m s^{-1} while daily mean SASS-2 minus island wind speed differences average –0.07 m s^{-1} over the islands. RMS differences between SASS-2 and the daily mean island data average 1.7 m s^{-1}; the SASS-1 RMS differences average 2.2 m s^{-1}. Because the Seasat wind algorithms yield solutions with more than one possible direction, a single direction can only be selected from the others using ancillary information. We compared direction results from the objective selection method developed at the Goddard Laboratory for Atmospheres, as well as results from the somewhat artificial method of selecting the SASS direction closest in agreement with the comparison island direction. When averaged over tens of days the Goddard directions agree closely with the island observations. However, Goddard daily average directions exhibit considerably higher variance than those measured at the islands. The closest direction technique gives daily mean SASS minus island RMS direction differences averaging 20 degrees over the nine islands; the Goddard RMS differences average 52 degrees. Day-to-day comparison figures of vector winds from GLA SASS-1 and the islands permit detailed examination of the SASS-derived wind fields in the tropical Pacific near the comparison islands.

SECTION I

1. INTRODUCTION

The winds derived from the Seasat-A Satellite Scatterometer (SASS) measurements have been the subject of great interest since the 1978 mission, because of the promise of radically improved wind observations over the world ocean. Due to the early end of the mission, only a few of the planned ground-truth validation experiments could be made, and the subsequent lack of sufficient high-quality independent wind data for comparison has limited our ability to resolve critical issues regarding the scatterometer's performance and the correct interpretation of its signal.

Operational weather observations were made of ocean winds independent of Seasat mission plans during the Seasat mission period, and we report here the results of a comparison study using such observations. Previous verification with *in situ* winds has been primarily in middle latitudes (GOASEX, JASIN, and NDBO buoys); here we compare winds observed from nine tropical Pacific islands with nearly contemporaneous measurements taken by SASS during overpasses of the islands.

2. THE SATELLITE DATA SETS

Seasat measurements were ended by a short circuit less than 4 months after the satellite was launched in June 1978. During the 96-day life of the mission the scatterometer indirectly observed near-surface winds, from an 800-km orbit, by measuring radar scatter from the centimeter-scale ocean surface roughness. The literature on Seasat and SASS is voluminous, and the newcomer to the subject will find O'Brien *et al.* (1982), and two journal special issues (Bernstein, 1982, and Kirwan *et al.*, 1983) good introductions.

While earlier work (Moore and Fung, 1979, present a historical review) showed that Seasat's K_u-band radar backscatter is clearly related to near-surface wind strength, the precise relationship is largely empirical and still under discussion. And, although scattering anisotropy allows extraction of wind direction from the normalized signal (sigma-0), there are two to four directions corresponding to a particular solution, so that direction is fundamentally ambiguous for this instrument. The candidate directions are often referred to as the wind aliases, and selection of the preferred one is called dealiasing.

We have examined two complete-mission data sets of SASS winds provided by the Jet Propulsion Laboratory. Both were prepared from sigma-0 values binned into a grid with 100-km resolution perpendicular to the satellite subtrack, work done at the Atmospheric Environment Service of Canada; Wentz (1986) presents details of the process. The first set was prepared using the SASS-1 wind vector algorithm made final in scatterometer verification against GOASEX and JASIN winds (see Schroeder *et al.*, 1982, and Jones *et al.*, 1982). The data set was processed further at the Goddard Space Flight Center, where an atmospheric general circulation model at the Goddard Laboratory for Atmospheres was used along with other information in an objective scheme to dealias the winds; see Atlas *et al.* (1987) and Baker *et al.* (1984) on this. We shall refer to this data set as SASS-1 and the dealiasing choice as GLA's.

The second data set uses a different wind vector algorithm to derive the winds, one developed by Wentz *et al.* (1984, 1986) in response to perceived significant shortcomings in the SASS-1 algorithm. These winds were dealiased by choosing the alias closest to the alias selected by the GLA scheme in the SASS-1 dealiasing. We shall refer to this data set as SASS-2.

3. THE TROPICAL PACIFIC SURFACE WIND DATA SET

The New Zealand Meteorological Service operates a network of surface observing stations on islands in the tropical Pacific, where wind speed and direction are reported several times per day. We chose nine of these stations near the Dateline situated in a rough line from 3°N to 11°S, where wind data are available during the Seasat mission period, for comparison with the SASS data sets.

Though the island winds are not of the same quality as state-of-the-art measurements from surface moorings (see, for example, Halpern, 1984), Luther and Harrison (1984), Harrison (1987), and Harrison and Luther (1989) have shown that they appear useful for a variety of studies of tropical Pacific variability. They also compare well with climatological monthly means based on surface observations from ships over the same time period, and have high coherence between adjacent islands at all resolved energetic periods. Most of the data used here are based on Beaufort observations of sea state, from the low-lying atolls While we recognize that there are differences between point data averaged from several-times-per-day observations and the nearly instantaneous area averaged winds from SASS, we believe the averaging scheme we use over these time and space scales in the tropics yields reasonable results.

4. COMPARISON RESULTS

For comparison against each island record we selected those SASS observations where the center of the 100-km SASS grid cell lay within a 2 × 2 degree square centered on that island. We computed daily averages of each record for comparison, using in the analysis those days where both scatterometer and *in situ* winds were measured. The complete-mission record is 96 days long, but gaps in both type records reduce the comparison time-series at the nine islands to lengths ranging from 34 to 66 points. We describe results for both the SASS-1 and SASS-2 data sets.

a. Closest Direction Alias Results

The ambiguity in SASS measured wind direction forces a choice of one from the (usually) four aliases before comparison can be done. In this section we discuss island wind comparison with SASS data sets created by choosing from each observation time's aliases the one closest in direction to the comparison island's daily averaged wind, for each of the nine islands – what we shall call the Closest Direction Alias, or CDA. CDA dealiasing has been used often in prior comparisons. Because the direction statistics of CDA dealiasing are close to the best possible and the alias selection is not independent of the comparison observation, the method is artificial but has value in comparison studies. The wind speeds vary little among the aliases, and are not much affected by the choice.

Figure 1a, showing the vector average winds over the entire 96-day mission at the nine islands, overlays the island winds (dark vectors) with CDA SASS-1 winds (light). Note that, except for Niulakita, individual island directions agree within 5 degrees; the average difference is 0.8 degrees, Niulakita included. In all cases SASS-1 wind speed is the greater, with an average difference of 1.2 m s^{-1}. The nine-island average wind speed over the complete-mission period is 5.1 m s^{-1}. Figure 1b presents the same comparison using SASS-2 data. Wind directions are

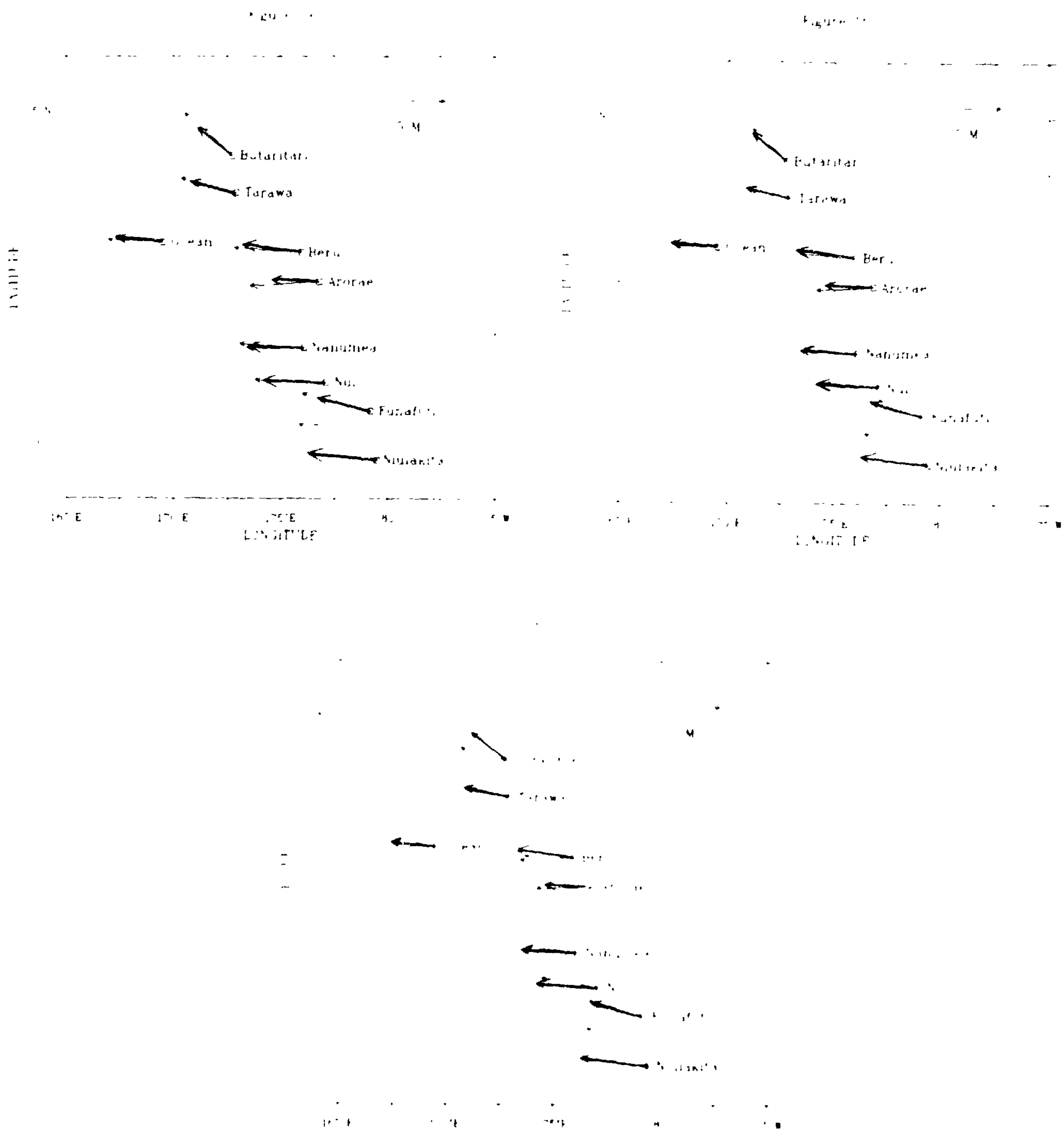


Figure 1. Complete-mission vector average winds, island observations (dark vectors) compared with SASS (light) (a) CDA SASS-1. (b) CDA SASS-2. (c) GLA SASS-2.

nearly identical, but SASS minus island speed differences now average −0.07 m s^{-1}. See Table 1 for SASS versus island statistics for each of the nine island locations.

RMS direction differences are on average 20 degrees for CDA dealiasing; RMS speed differences for SASS-1 average 2.2 m s^{-1}, while the SASS-2 average is 1.7 m s^{-1}. The design specification of these values for the scatterometer are ±20 degrees, and ±2 m s^{-1}, for winds above 4 m s^{-1}. SASS minus island results are listed in Table 2.

Correlation coefficients between SASS-1 and island wind speed time series are significant at the 5% level for eight of the nine islands, while for direction this is true at six of the nine; four are significant at the 1% level for both speed and direction. Every third daily value at the islands may be considered independent, based on examination of the wind autocorrelation statistics.

b. GLA Dealiased Results

In general, as an independent observation of the wind will not be available, the CDA dealiasing technique cannot be used; we now examine results with the GLA dealiased data set. Since the GLA wind directions are selected by comparing aliases with winds forecast by a general circulation model, this method of dealiasing can be available on an operational and ocean-wide basis. In the GLA scheme SASS measurements within 3 hours of model 6-hourly forecasts are dealiased in a three-pass procedure. Two-alias reports are dealiased in the first pass, where forecast winds from the nearest four grid points (the grid is 4 degrees in latitude by 5 degrees in longitude) are bilinearly interpolated to each SASS wind location; the SASS solution closest to that direction is chosen provided it is within 75 degrees, otherwise no dealiasing is done there. Following modification of the wind field taking the dealiased winds into account, two similarly iterated passes attempt to dealias the more ambiguous winds, specifying narrow, then wider directional difference limits between the analysis and selected SASS alias directions; in the last pass 75 degrees is again the maximum difference allowed, otherwise a measurement is not dealiased. It was possible to dealias three-fourths of the data set with this method.

The CDA and GLA methods selected the same aliases 67% of the time both methods chose an alias. Figure 1c shows the vector average winds as in Fig. 1b except the GLA dealias choice is used; the nine-island average direction difference is now 5 degrees and the RMS direction difference averages 52 degrees. Correlation coefficients for direction between island and GLA SASS winds are significant at the 5% (and 1%) level for one comparison only.

c. Variability and Steadiness Results

The variability in the SASS winds is greater than that in the island winds, although this is more apparent in speed than direction for CDA dealiasing. Here, where the average island wind speed standard deviation is 1.5 m s^{-1}, for SASS-1 it is 2.3 m s^{-1} and for SASS-2 it is 2.1 m s^{-1}

TABLE 1 Island and SASS daily average wind measurement statistics

	Butaritari	Tarawa	Ocean	Beru	Arorae	Nanumea	Nui	Funafuti	Niulakita
No. of obs (GLA SASS-1)	40	34	58	65	66	64	44	56	54
Average speed ($m\ s^{-1}$)									
Island	4.2	4.1	4.4	5.6	4.5	5.3	5.9	5.1	6.4
SASS-1	5.9	5.3	5.2	6.4	6.6	6.1	6.7	6.7	8.0
SASS-2	4.4	4.0	3.9	5.2	5.2	4.8	5.5	5.3	6.8
Speed std dev ($m\ s^{-1}$)									
Island	1.1	1.2	1.2	1.3	1.1	2.1	2.1	2.0	1.1
SASS-1	2.0	2.1	2.0	2.2	2.3	2.1	2.4	2.2	2.9
SASS-2	1.7	2.0	1.8	2.0	2.2	2.1	2.3	2.1	2.9
Average direction (degrees)									
Island	127	103	95	97	92	91	92	104	96
CDA SASS-1	131	[illegible]	92	94	86	93	92	104	114
GLA SASS-1	102	99	89	86	86	96	100	102	120
Direction std dev (degrees)									
Island	20	18	30	21	8	45	51	44	40
CDA SASS-1	28	26	34	22	16	46	49	44	37
GLA SASS-1	54	54	72	54	55	56	50	47	53
Steadiness									
Island	0.94	0.92	0.92	0.92	0.98	0.79	0.72	0.80	0.83
CDA SASS-1	0.90	0.89	0.93	0.92	0.94	[illegible]	0.79	0.81	0.87
GLA SASS-1	0.73	0.71	0.59	0.75	0.75	0.75	0.74	0.76	0.77
Correlation with island *									
SASS-1 speed	0.47	**0.64**	**0.68**	**0.42**	**0.45**	**0.60**	**0.60**	**0.84**	**0.71**
CDA SASS-1 direction	**0.51**	**0.71**	**0.83**	**0.67**	0.11	0.06	**0.46**	0.43	**0.87**
GLA SASS-1 direction	−0.17	0.26	0.12	0.16	0.06	−0.08	0.36	**0.78**	0.41

* Correlations significant at the 5% level are **bold**, those also significant at the 1% level are underlined as well

TABLE 2. Daily average wind difference (SASS minus island) statistics.

	Butaritari	Tarawa	Ocean	Beru	Arorae	Nanumea	Nui	Funafuti	Niulakita
RMS speed diff. (m s^{-1})									
SASS-1	2.4	1.9	1.7	2.2	2.9	2.1	2.2	1.9	2.7
SASS-2	1.6	1.4	1.5	1.9	2.1	1.9	1.9	1.1	2.2
Speed diff. std dev (m s^{-1})									
SASS-1	1.7	1.6	1.5	2.0	2.1	1.9	2.0	1.2	2.3
SASS-2	1.6	1.4	1.4	1.8	2.0	1.9	1.9	1.9	2.2
RMS direction diff. (degrees)									
CDA SASS-1	24	18	18	18	18	23	25	14	24
GLA SASS-1	64	52	71	57	56	55	45	29	42
Direction diff. std dev (degrees)									
CDA SASS-1	24	19	19	18	17	23	25	14	19
GLA SASS-1	52	52	72	55	55	56	45	30	38

The direction standard deviation averages 31 degrees for the island observations; for CDA dealiased SASS it is 34 degrees, and 55 degrees for the GLA dealiases.

Differences in variability in the wind direction are shown clearly in the wind roses of Fig. 2. Figure 2a is from the island record, 2b the GLA SASS-1 record, and 2c the CDA SASS-1 record. Steadiness (the ratio of the magnitude of the mean wind vector to the average speed of the wind) averaged over the nine islands is 0.87; SASS-1 averages are also 0.87 for CDA dealiases, but are 0.73 for GLA dealiases.

Scatterplot diagrams offer a perspective on the typical observational differences in both speed and direction (Fig. 3). Here the scatter of island measurements versus SASS for the nine islands is plotted in the four panels. Panel 3a is of SASS-1 speed and 3b the same for SASS-2. Panels 3c and 3d show direction scatter for SASS-1 GLA and CDA dealiasing respectively.

There is scatter in the comparison records, but the complete-mission averages agree closely in speed and direction; differences appear to be random rather than systematic. Knowledge of the averaging time required to sufficiently reduce these differences may prove valuable in assessing the utility of the SASS winds. Figure 4 presents the RMS differences of SASS-2 GLA dealiased winds and island winds as a function of averaging time. RMS differences in speed (Fig. 4a) fall slowly with length of average, but more rapidly for direction (Fig. 4b), from a mean of 52 degrees to below 20 degrees at 12 days.

d. Day-to-Day Comparison

While the statistical properties of the comparison offer a summary description, a day-to-day presentation of the SASS winds and the island winds together permits detailed examination of the comparison series.

Figures 5 through 8 present daily average direction and speed comparisons separately for each of the nine islands. In each of the figures, the island time series values are plotted using x's, and where uninterrupted, connected with a line; the SASS values are plotted using unconnected squares. In these figures, the time series at the island locations are ordered by latitude from north to south. Figure 5 is of the island and SASS-1 GLA direction time series. Observations from the islands show generally greater directional variance south of and away from the Equator, while this is not true of GLA directions; these maintain a roughly constant direction standard deviation comparable to the island standard deviation at the southern islands. Figure 6 also shows island wind direction, but with SASS-1 CDA aliases overlaid. Island and CDA directions agree more closely, but recall that the CDA alias is the SASS alias closest in direction to the island wind. Figure 7 compares island wind speeds with SASS-1 speeds, and Fig. 8 island speeds with SASS-2 speeds. The latitudinal trends of speed standard deviation are similar to the trends in direction variability, with the off-equatorial southern islands possessing a higher standard

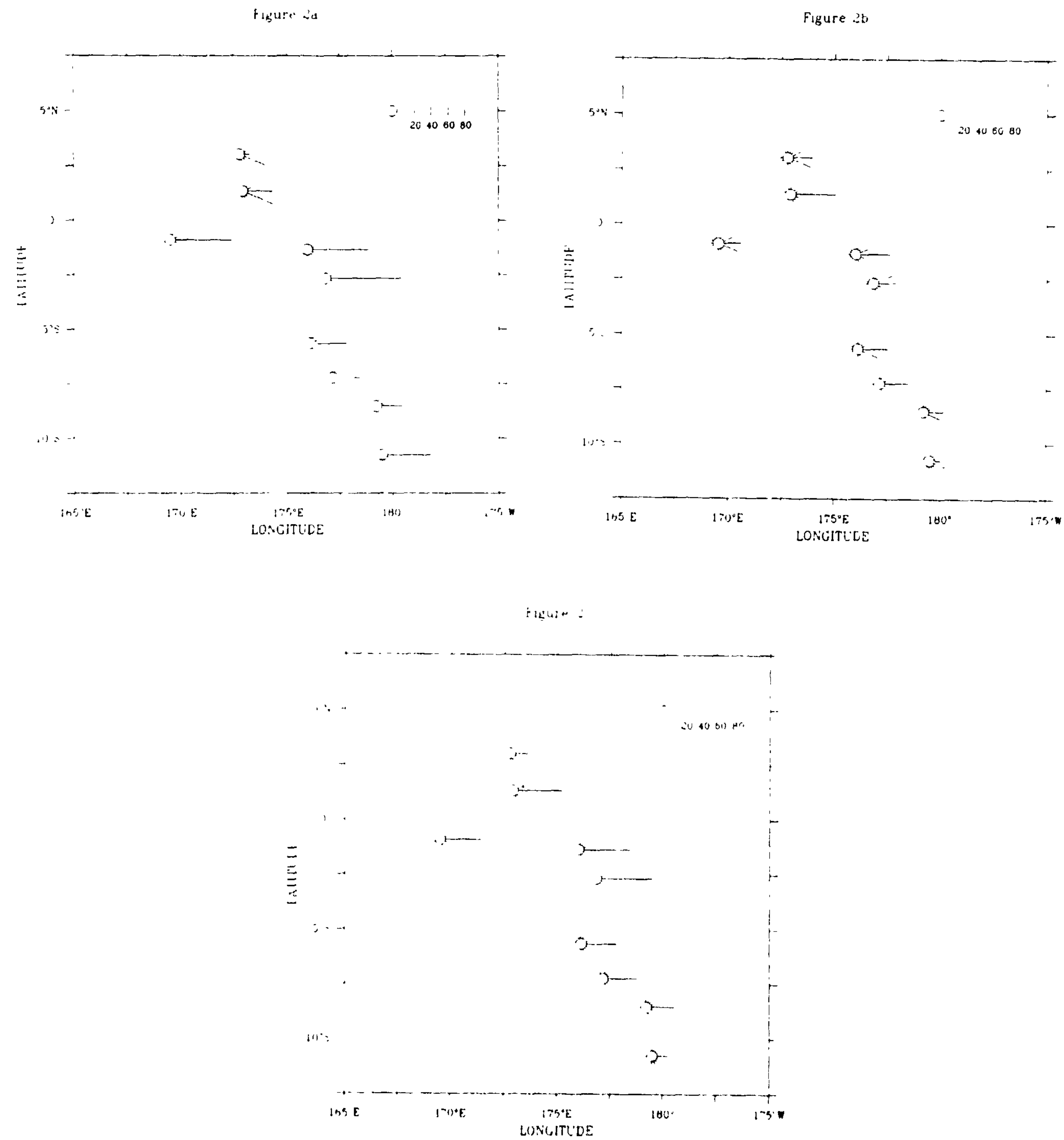


Figure 2. Percent of observations with winds from a given direction. (a) Island observations. (b) GLA SASS-1. (c) CDA SASS-1.

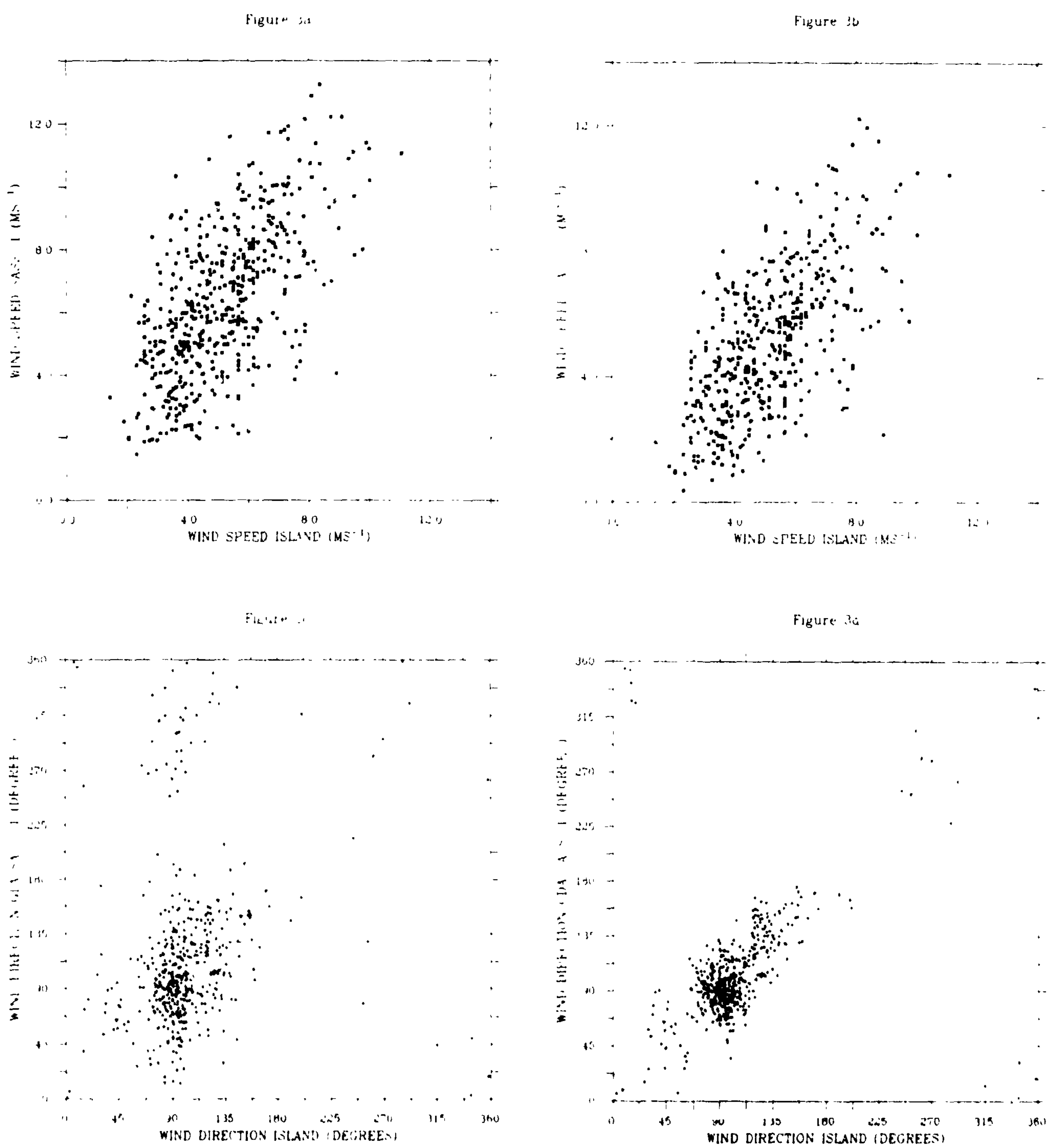


Figure 3. Scatter plots of island observations and SASS. (a) Wind speed, island and SASS-1. (b) Wind speed, island and SASS-2. (c) Wind direction, island and GLA SASS-1. (d) Wind direction, island and CDA SASS-1.

Figure 4. RMS differences between island observations and GLA SASS-2 as a function of averaging time. (a) Speed. (b) Direction.

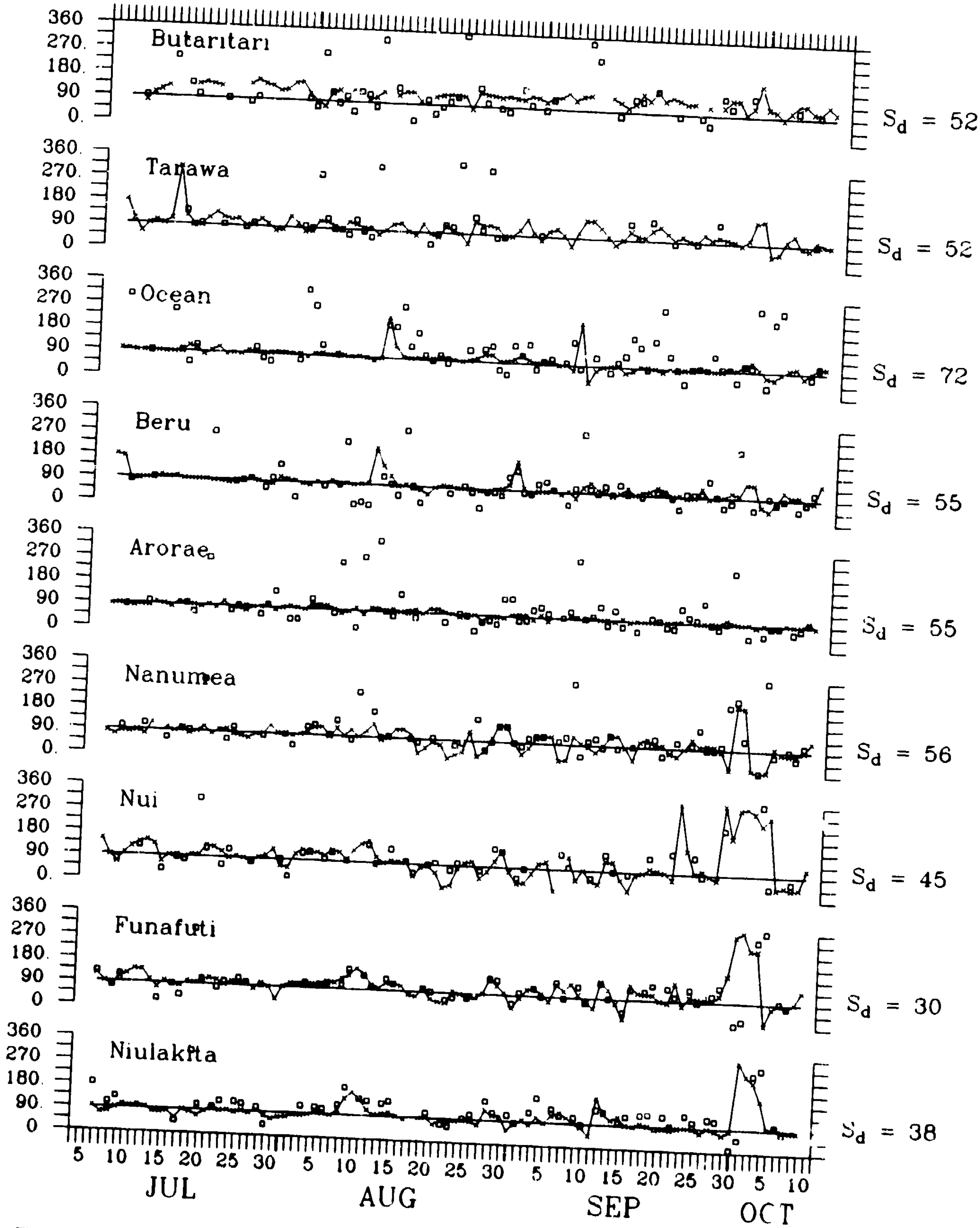


Figure 5. Direction (degrees) of daily average winds at the nine islands, and GLA SASS-1. The standard deviation of the daily average direction difference (S_d, GLA minus island) is given at the right for each island.

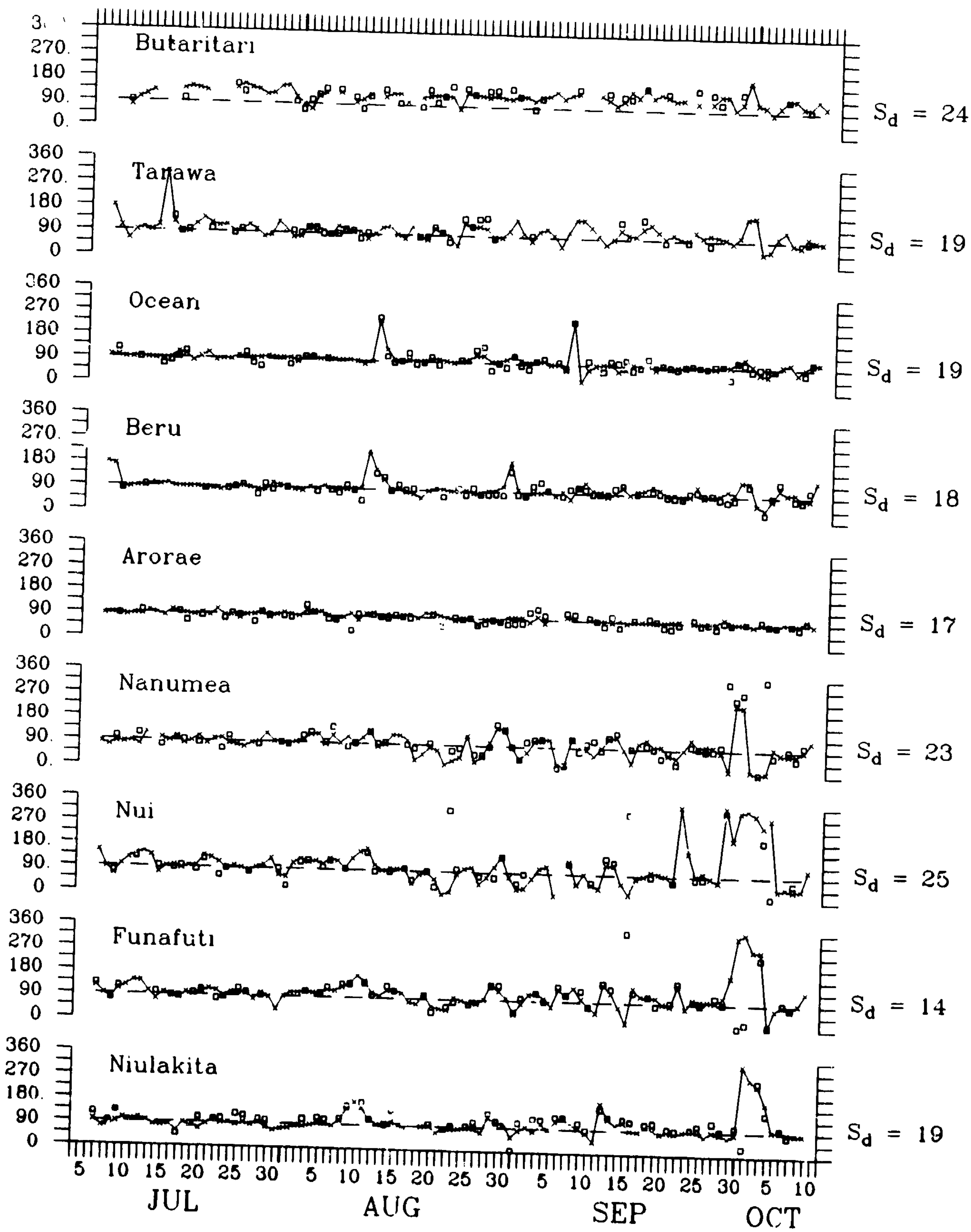


Figure 6. Direction (degrees) of daily average winds at the nine islands, and CDA SASS-1. The standard deviation of the daily average direction difference (S_d, CDA minus island) is given at the right for each island.

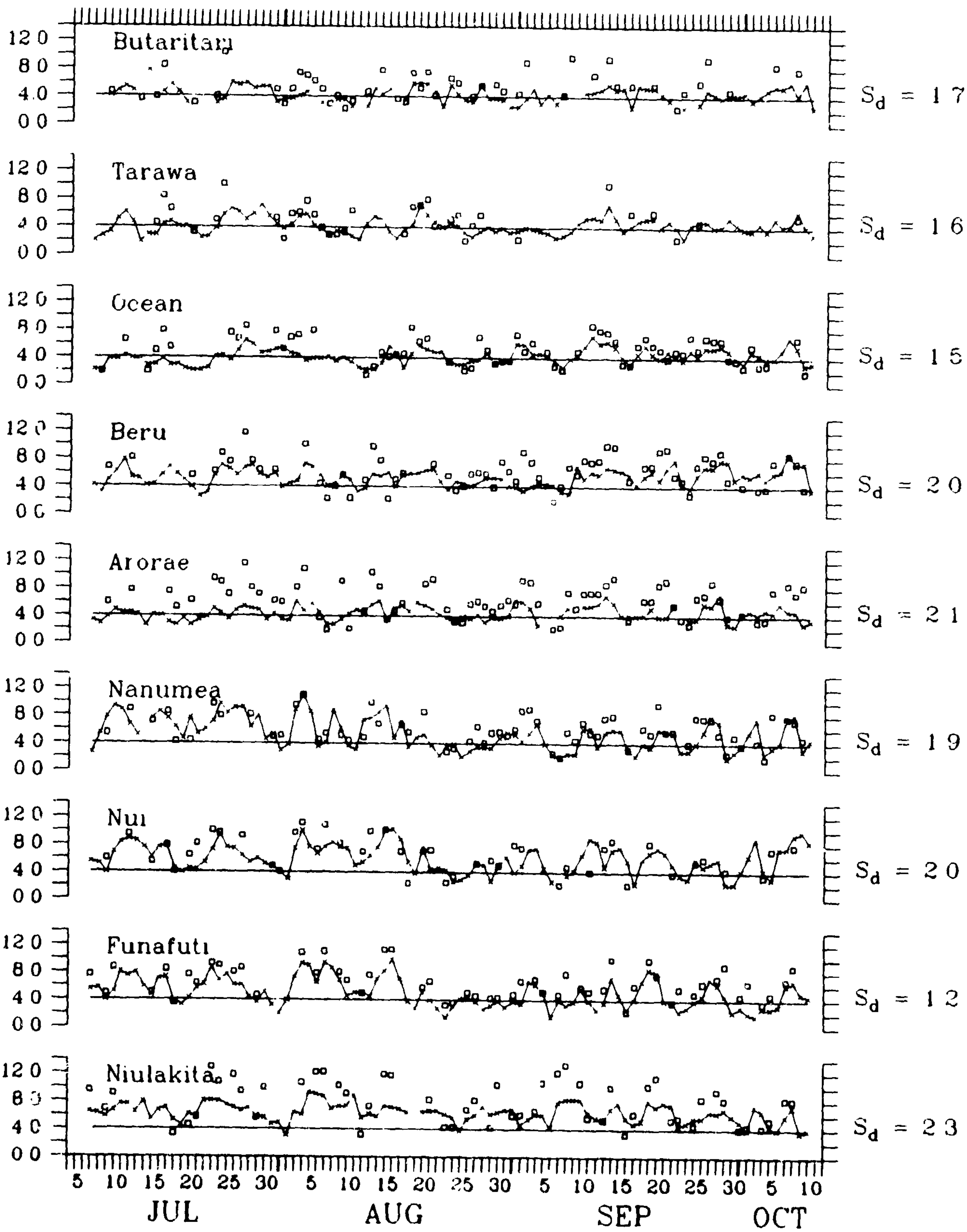


Figure 7. Speed (m s^{-1}) of daily average winds at the nine islands, and SASS-1. The standard deviation of the daily average speed difference (S_d, SASS-1 minus island) is given at the right for each island.

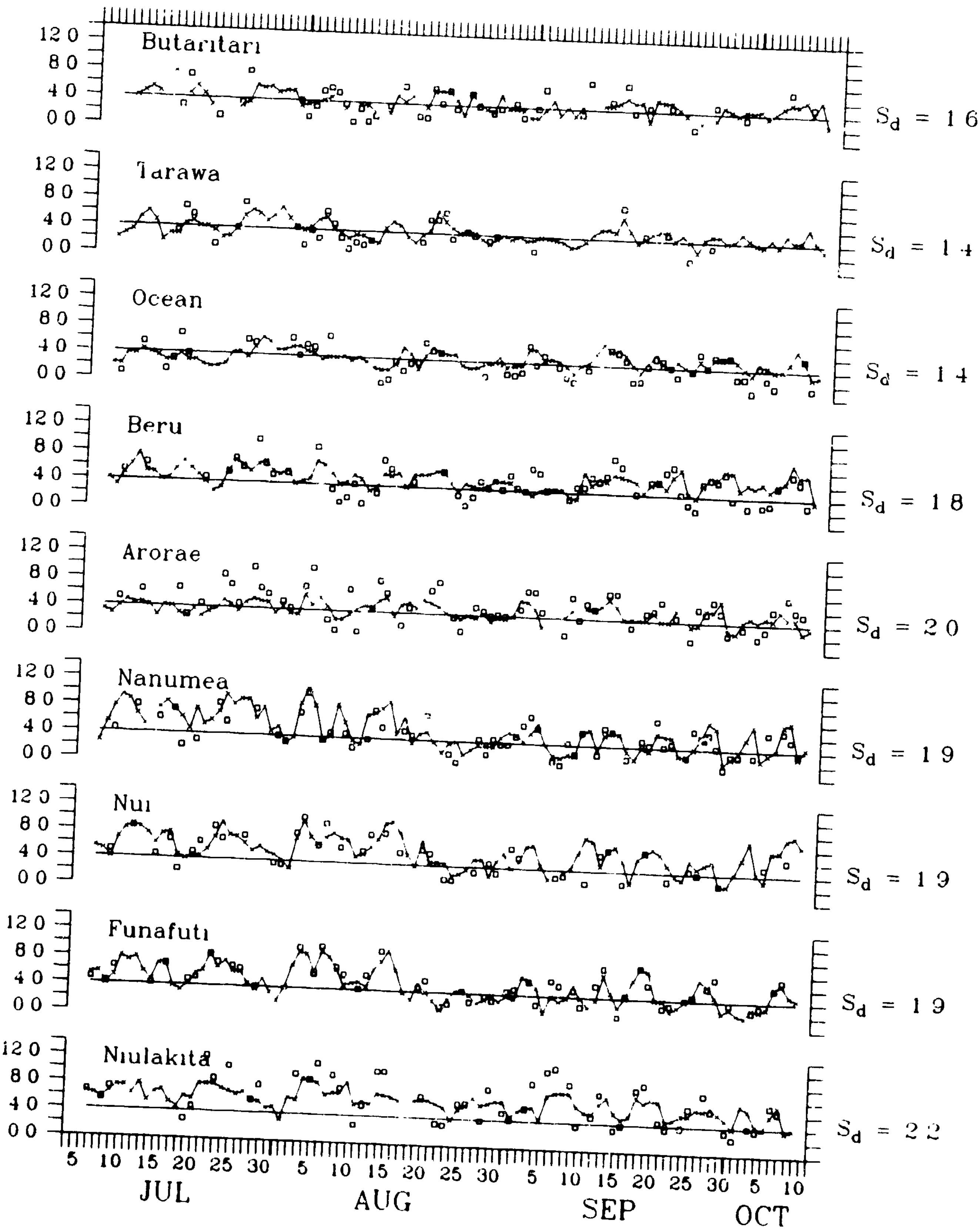


Figure 8. Speed (m s^{-1}) of daily average winds at the nine islands, and SASS-2. The standard deviation of the daily average speed difference (S_d, SASS-2 minus island) is given at the right for each island.

deviation than the equatorial group, and the SASS values roughly constant and (for SASS-2) comparable to the southern island values.

Perhaps the most intriguing figures in this report are those giving the highest amount of detail in the winds. In Section II we present a day-to-day comparison of the island and SASS vector winds; the island winds are daily averages, while the SASS winds are the instantaneous GLA dealiased SASS-1 winds measured within the study area in a 24-hour period. We chose the GLA SASS-1 winds for these figures as this is the data set directly dealiased ocean-wide by the Goddard procedure. Showing the relationship between SASS-1 and SASS-2, Fig. 9 presents a comparison of the results of the two wind vector algorithms. Figure 9a plots SASS-1 GLA versus SASS-2 daily average directions from the nine island locations; 9b is a similar plot of SASS-1 versus SASS-2 daily average wind speeds. While both direction and speed correlate closely, the difference in average wind speed between the two algorithms is apparent.

The geographical region of these figures extends from 20°S to 20°N, and extends 60 degrees in longitude, from 145°E to 155°W; the islands are approximately centered in this area. The figures include all winds used in the comparisons and present the spatial and temporal variability of the SASS winds in detail. Note that the SASS winds usually occur in double strips, each about 5 degrees wide; strips running from lower right to upper left are along the track of the satellite ascending from south to north. The double strip resulted from SASS radar scans on either side of the satellite subtrack. Strips running from upper right to lower left are along the track of the satellite descending, travelling from north to south. The approximately 25 degrees of longitude separating sequential ascending or descending strips results from the rotation of the earth. The satellite circled the earth 14 times daily, and scanned the entire global ocean once every 3 days. Single strips occur when SASS was scanning only one side of the spacecraft, and gaps in the strips occur; this can be due to the GLA algorithm not choosing an alias at those locations.

There are examples of very good and also very poor agreement between the island and SASS vector winds in these figures. The comparison record begins on July 7 with sparse SASS coverage near the islands, and few serious inconsistencies between the two series; winds near the islands are generally easterly. On July 14 anomalous northwest winds are tracked in both series near the Equator and 175°E, and near-island SASS winds are similar to island winds for several days. On August 12 the island records show marked spatial vector differences, but the nearby SASS winds agree in most cases. Other periods of confused patterns in both the island and SASS records show varying degrees of similarity in the vector winds, for example the period from September 30 through 3 October. The August 12 figure illustrates a striking characteristic of the GLA winds, where (here near Funafuti and Niulakita) differences in the wind direction between ascending and descending tracks are well over 90 degrees. Ascending and descending tracks in a single day are roughly 12 hours apart in small regions near the equator. During

Figure 9. Scatterplot comparing SASS-1 and SASS-2 winds at the island locations. (a) Wind direction. (b) Wind speed.

periods of convective activity these changes may be entirely consistent with atmospheri condi-tions. However, the several days around 20 July have steady easterly winds at the islands, and the reversal of the SASS GLA wind between ascending and descending tracks near the center of the figure may be more questionable; but also note that the island winds nearby are quite weak on that day. Instances of this type of difference between crossing tracks are not infrequent in the GLA SASS data.

A possibly related situation, where there are abrupt changes in wind direction along a single satellite track, occurs commonly For examples, see July 20 (west of Beru and Arorae on the ascending track), August 16, and September 4 and 17. At least some of these abrupt changes are the result of the development of intense convection by the GLA GCM and the coarse resolu-tion of the model at the time the dealiasing was performed (R. Atlas, personal communication). Due to the grid size, the model wind at a grid point affects the dealiasing choice up to 8 degrees in latitude and 10 degrees in longitude. The model may plausibly simulate the response to unstable atmospheric conditions, but the implied scale of convective activity is large; resulting model winds influence selection of SASS aliases in that area.

There appears to be considerable improvement possible in the dealiasing process, unless the island winds are very misleading. Nonetheless, the dealiased SASS winds provide a fascinat-ing look at the high frequency variability of the wind over the ocean, heretofore unseen. Further study in the eastern Pacific, where the winds are much stronger and more steady, may help determine whether the unusual behavior of the GLA winds noted near the islands is associated with the generally weak wind conditions in that area, or possibly due to other characteristics of the dealiasing method.

5. DISCUSSION OF RESULTS

These comparisons support the conclusions of other investigators, that SASS measure-ments can agree with *in situ* winds very well. Yet over the entire set of islands there is consider-able scatter in the comparison, and correlation coefficients of the daily average GLA directions with the island winds are generally low.

We find that the mission-average wind speeds from the SASS-2 data set are very similar to comparable averages from the tropical islands, while speeds from the SASS-1 data set are consistently about 1 m s^{-1} higher than the island data. A bias of this amount in SASS-1 results, toward wind speed higher than observed from buoys, has been noted previously (e.g., Jones *et al.*, 1982); Wentz *et al.* (1986) reported SASS-2 results very similar to ours. As the island data are primarily composed of Beaufort observations, we can offer this as independent support that the SASS-2 wind vector algorithm provides low-frequency wind speed results directly compara-ble with Beaufort surface wind observations. At shorter time periods there is less agreement between wind speeds, but the SASS-2 minus island RMS differences are generally lower than the

2 m s^{-1} design criterion. The SASS-1 minus island RMS differences are about 0.5 m s^{-1} higher than these.

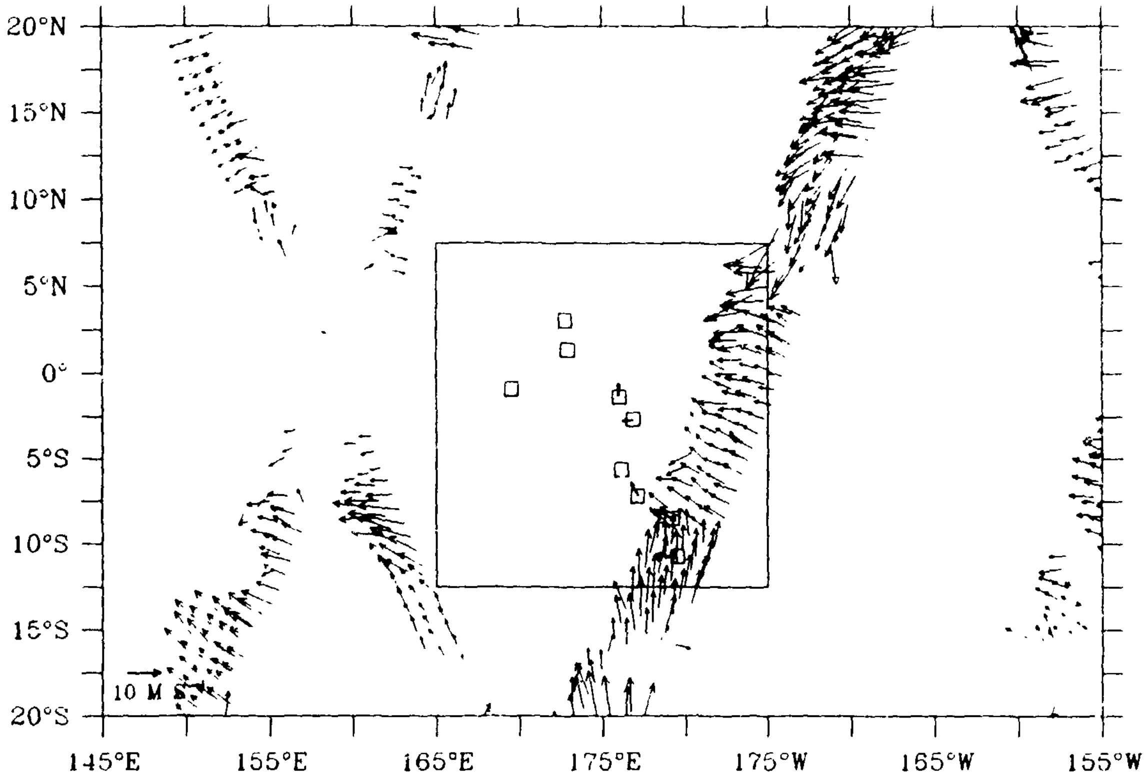
Results concerning wind direction are less simple to summarize. Using the CDA dealiasing method, SASS design specifications are met, but this method does not address the question whether an independent selection of direction will yield comparisons within specifications. Earlier work that included trained analysts in the dealiasing process compared favorably with specificiations; Wurtele *et al.* (1982) for example successfully dealiased a limited subset of the SASS winds independent of the comparison data. Baker *et al* (1984) used a version of the GLA scheme which included subjective enhancement of the initial objectively determined wind field to dealias selected regions of a 4-day subset of the SASS data set. For this period they report the subjective re-analysis changed 21% of the wind vector directions, and that 10% of the objectively dealiased vectors were deleted, indicating the subjective analysis had value. There are however over 2.6 million wind vectors to be dealiased in the complete-mission (96-day) record; there is strong motivation to find objective means.

Our comparisons indicate that the winds dealiased by the objective GLA procedure do not meet the SASS RMS directional difference specification by a substantial amount, using the island winds as a standard. Although this method chose the same alias as the CDA dealiasing 67% of the time, the remaining 33% typically doubled the RMS direction difference, compared with the CDA dealiased winds. Magnitudes of the difference in wind directions were non-trivial; 16% of SASS-1 GLA dealiased winds differed from the island winds by more than 60 degrees. While comparing dealiasing methods is not the same as comparing observations, it is worth noting that Atlas *et al.* (1987) compared SASS winds dealiased by the objective GLA scheme with a subset of the SASS record subjectively dealiased by Peteherych *et al* (1984) and found that overall both methods chose the same alias 73% of the time; 13% of the winds differed by more than 60 degrees.

It should be said that our comparison study is a demanding one for the Seasat scatterometer, since the average wind speed over the mission period at the nine islands is just over 5 m s^{-1}. Daily average winds are often less than 4 m s^{-1} at some of the islands; these are below the lower limit of wind speed measurement sensitivity specified for SASS. SASS sensitivity to direction may well decrease at lower wind speeds; Schroeder *et al* (1982) present SASS minus JASIN ground-truth directional differences as a function of wind speed in their Table 4 which support this possibility.

We are hesitant to assert that the island winds should be treated with the same confidence as wind from buoys; many observer and micrometeorological issues cannot be addressed in the present island wind data set. Nonetheless this study should suggest caution in the uncritical acceptance of the objective GLA dealias choices. Overall these results indicate that the scatterometer did possess the ability to measure tropical ocean near-surface wind speed within specifications of the instrument, and that better modeling of the backscatter-wind relationship has resulted from the continued study of SASS measurements; however, difficulty in dealiasing the winds, or imprecision in direction finding ability, may require appropriate time or space averaging to reduce scatter in the measured wind field.

SECTION II



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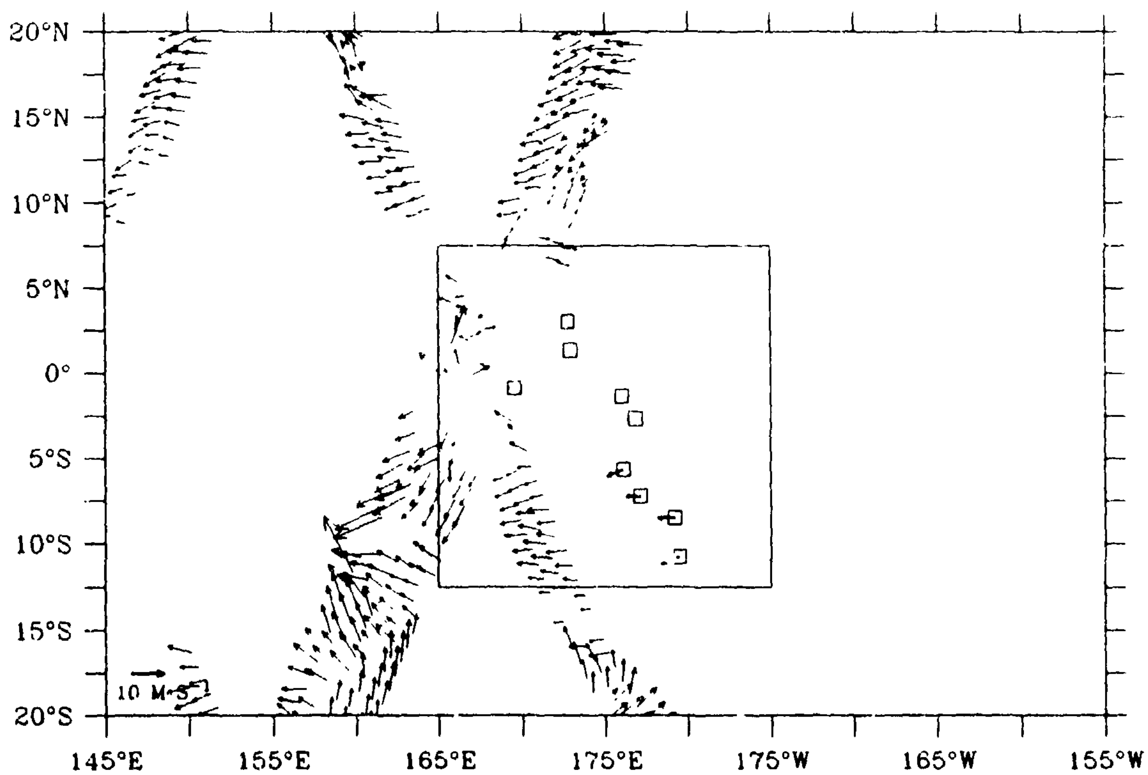

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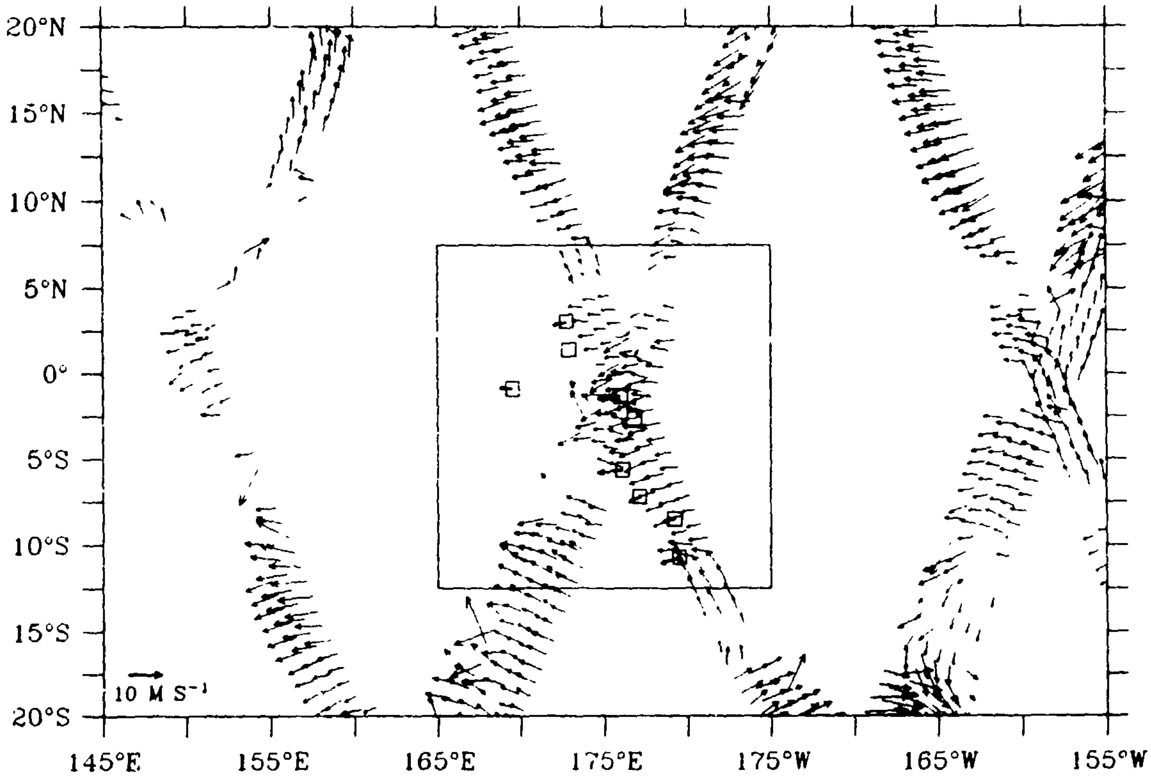

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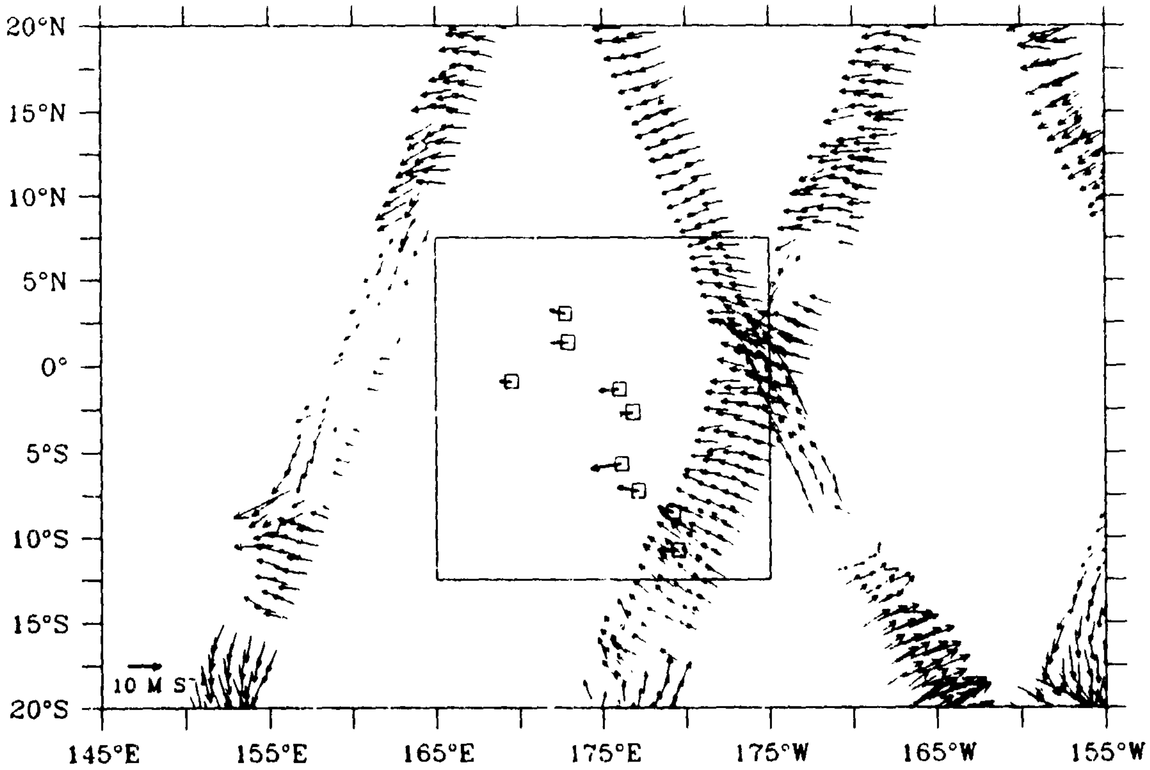

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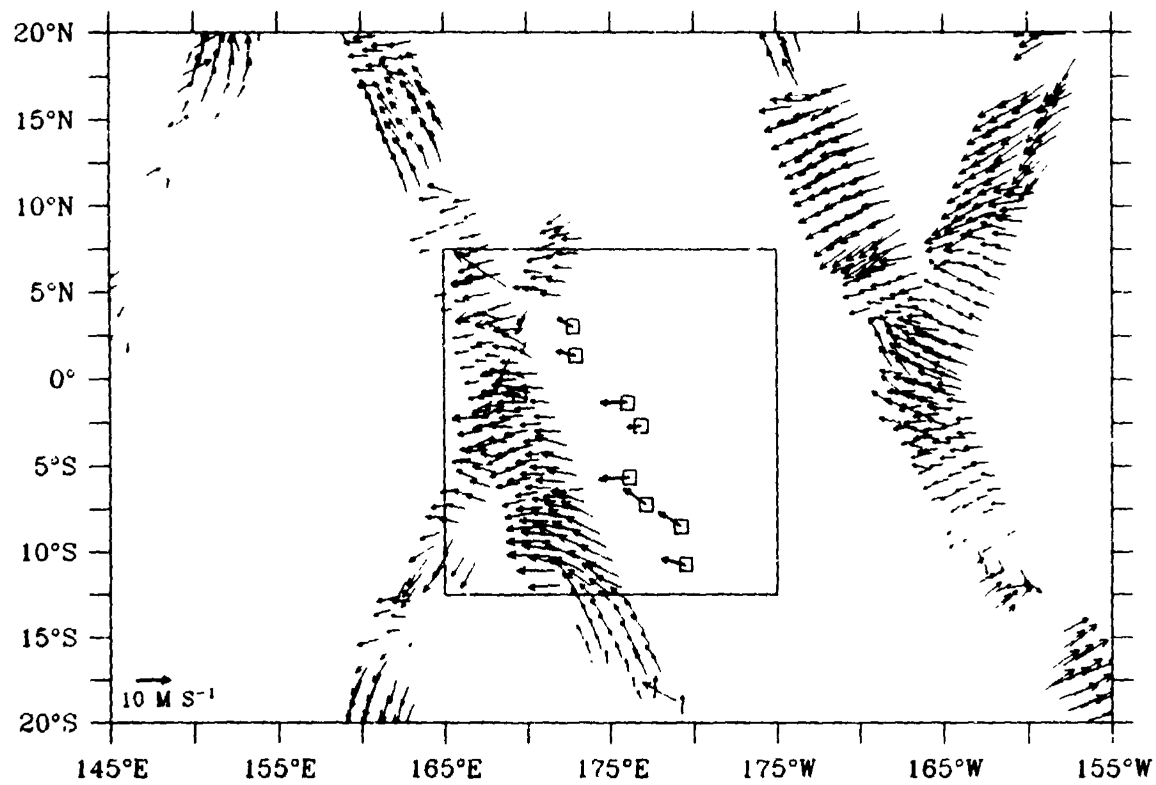

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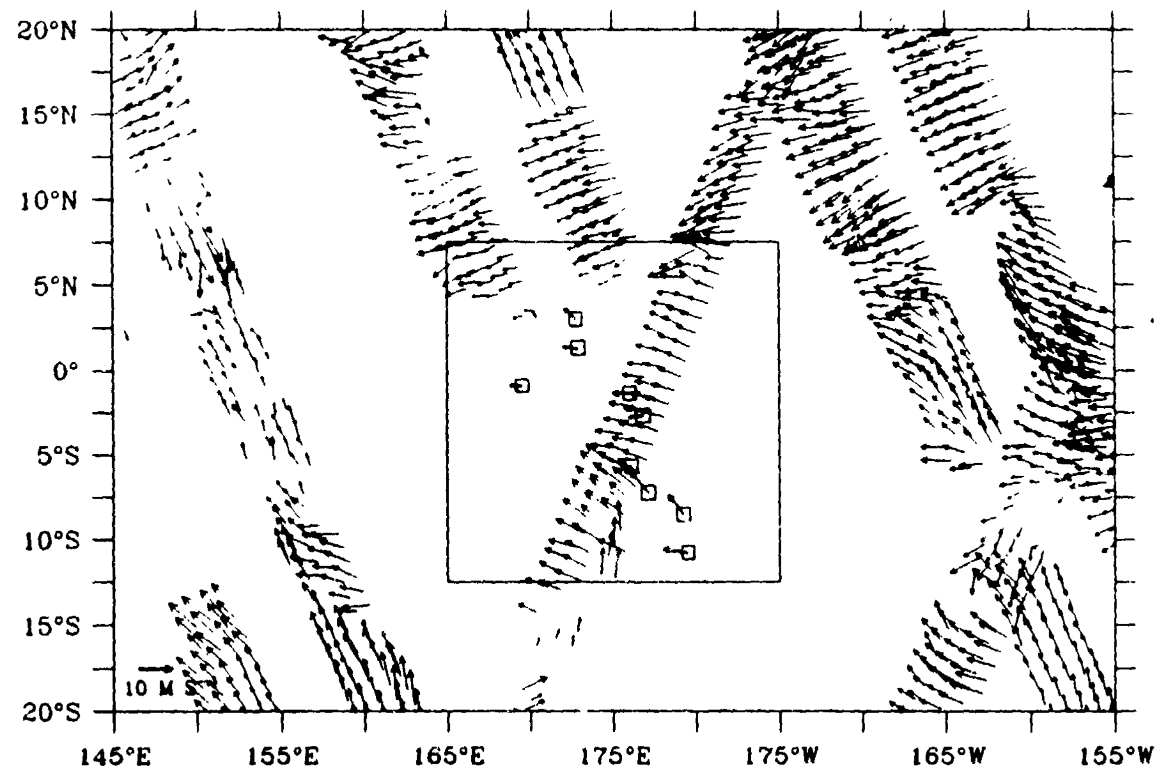

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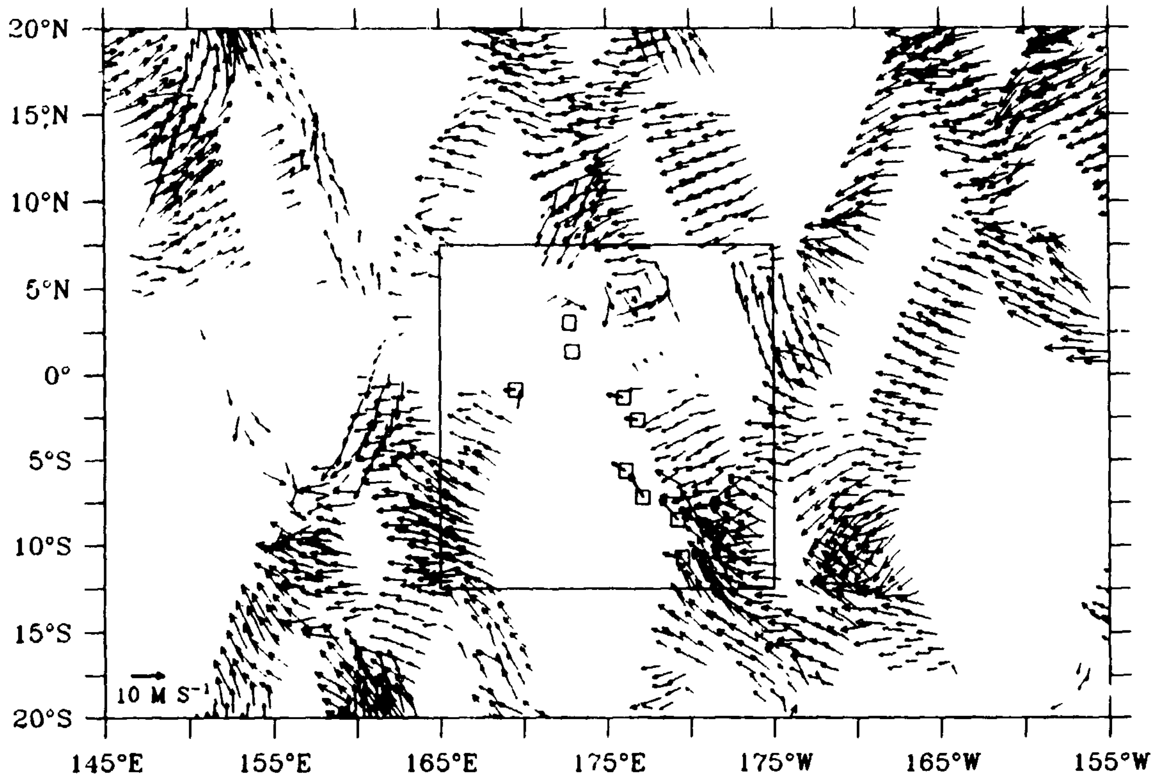

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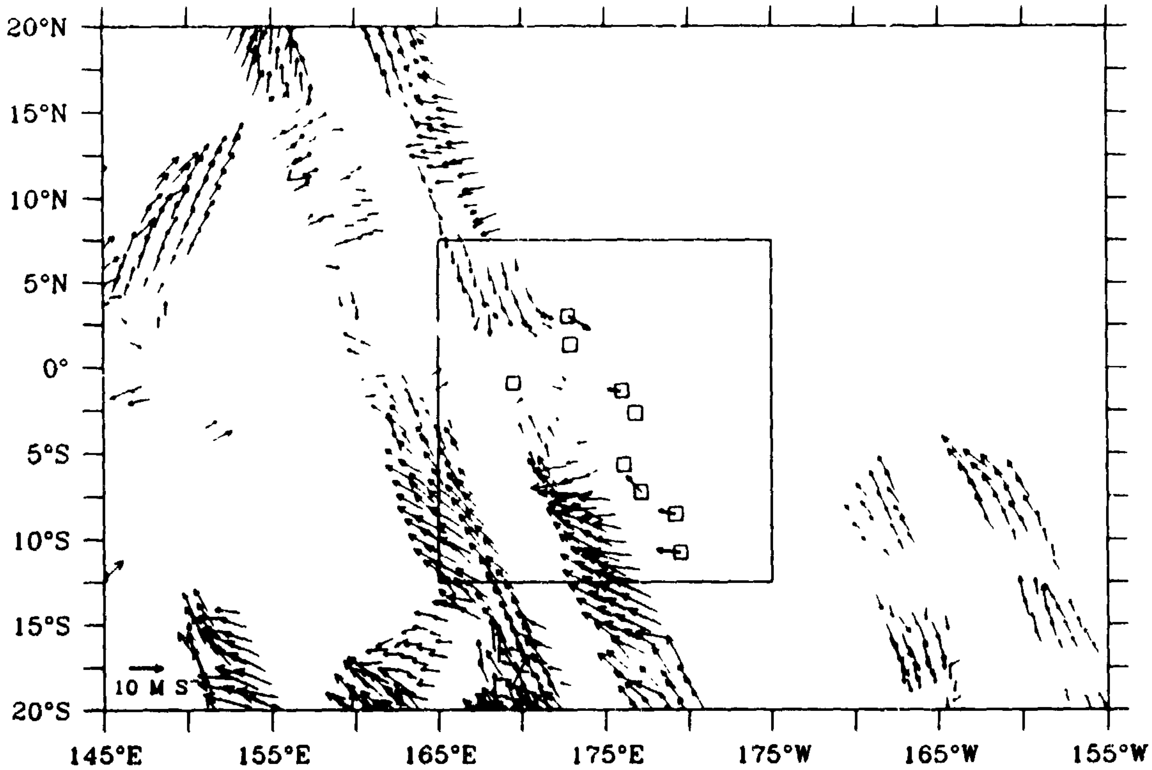

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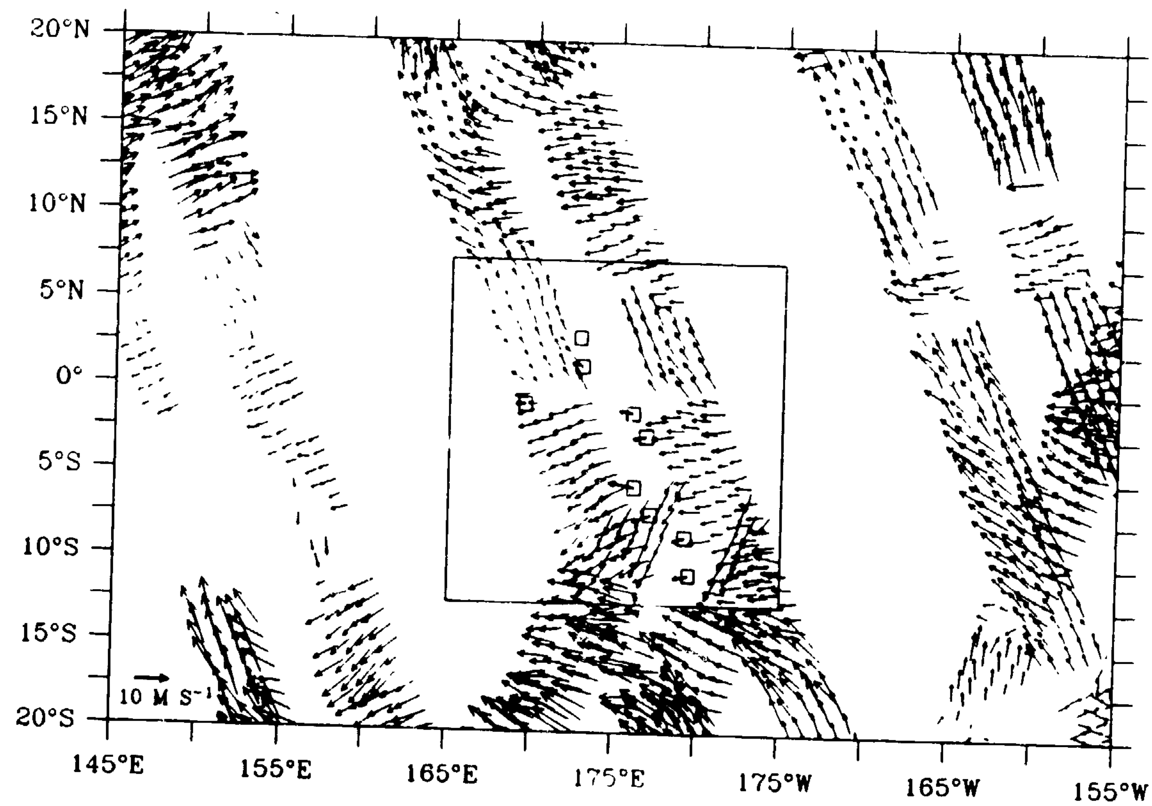

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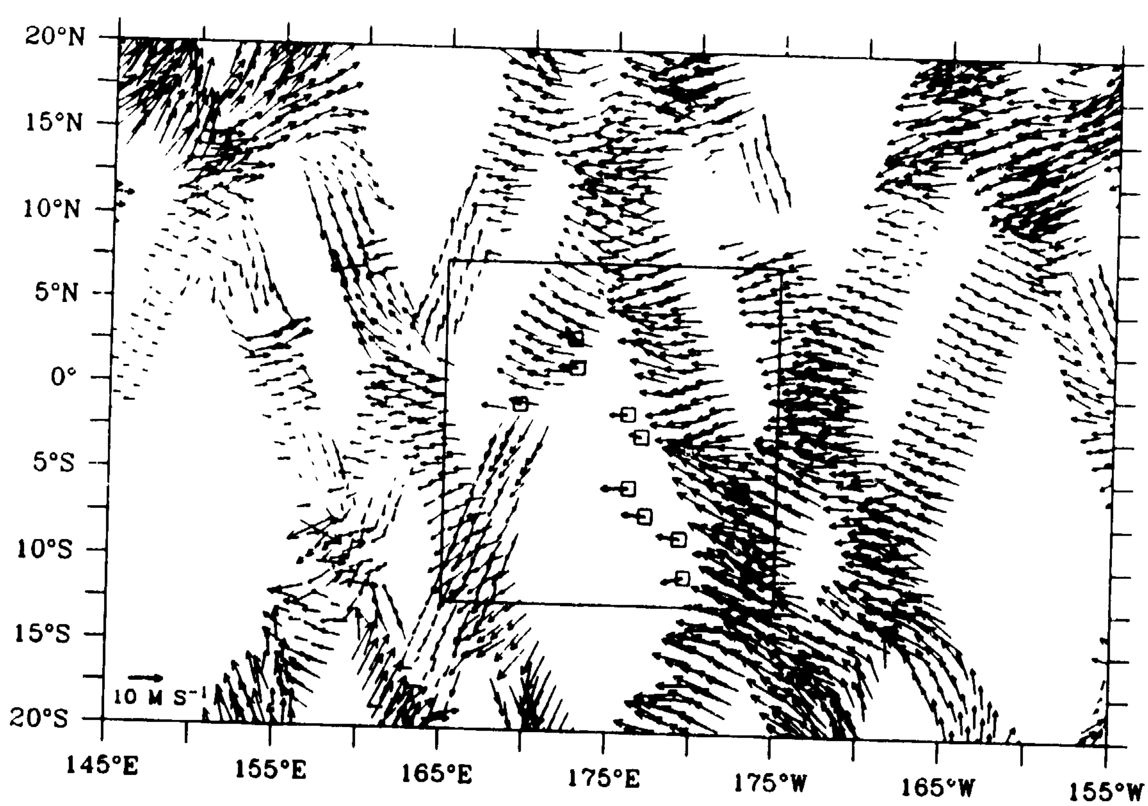

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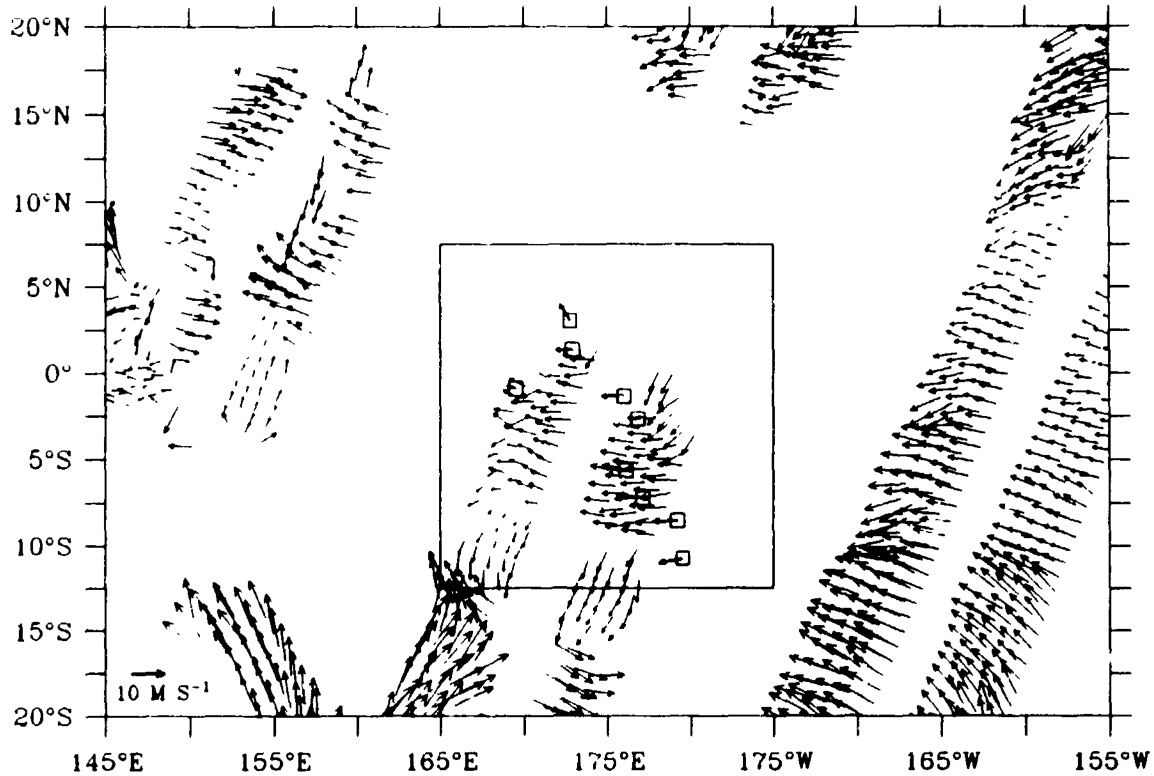

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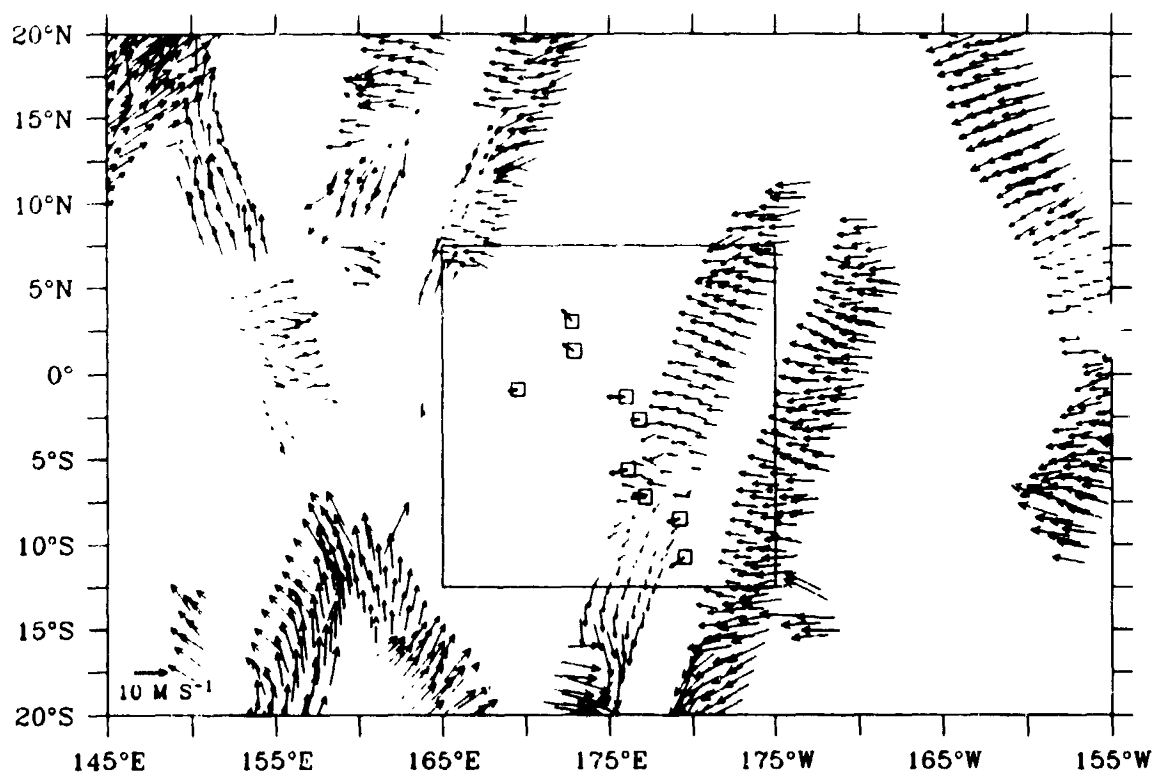

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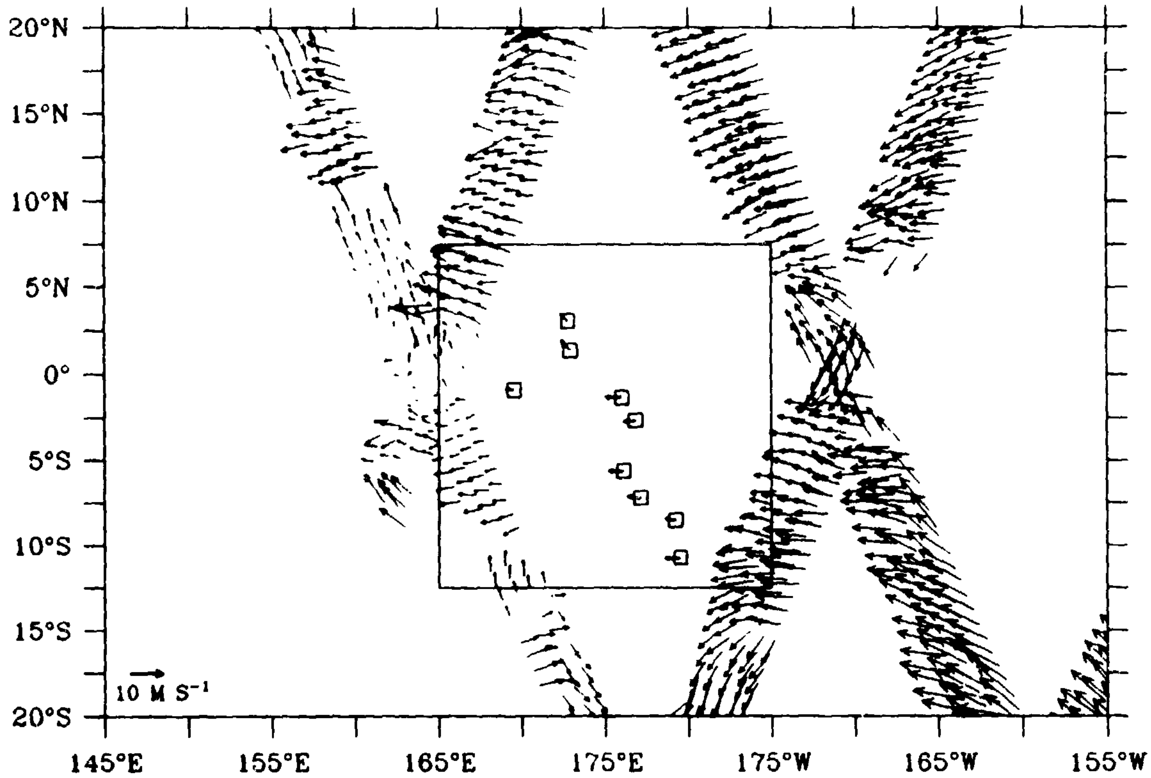

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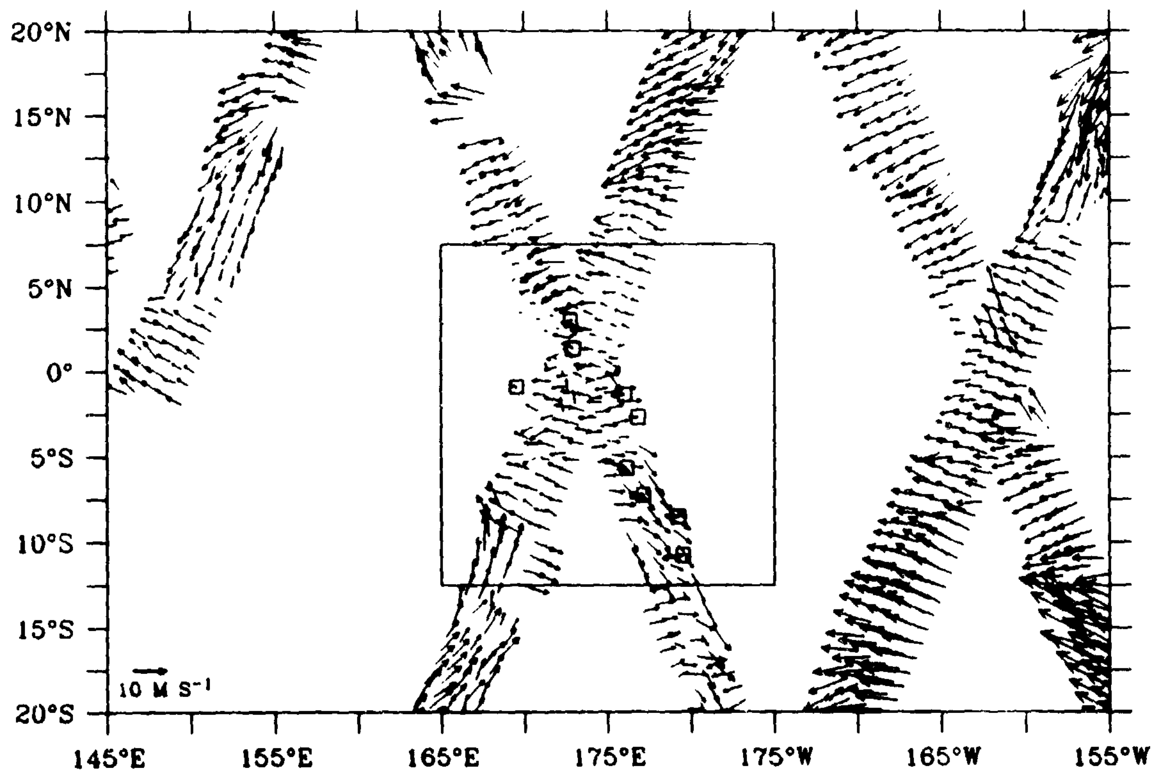

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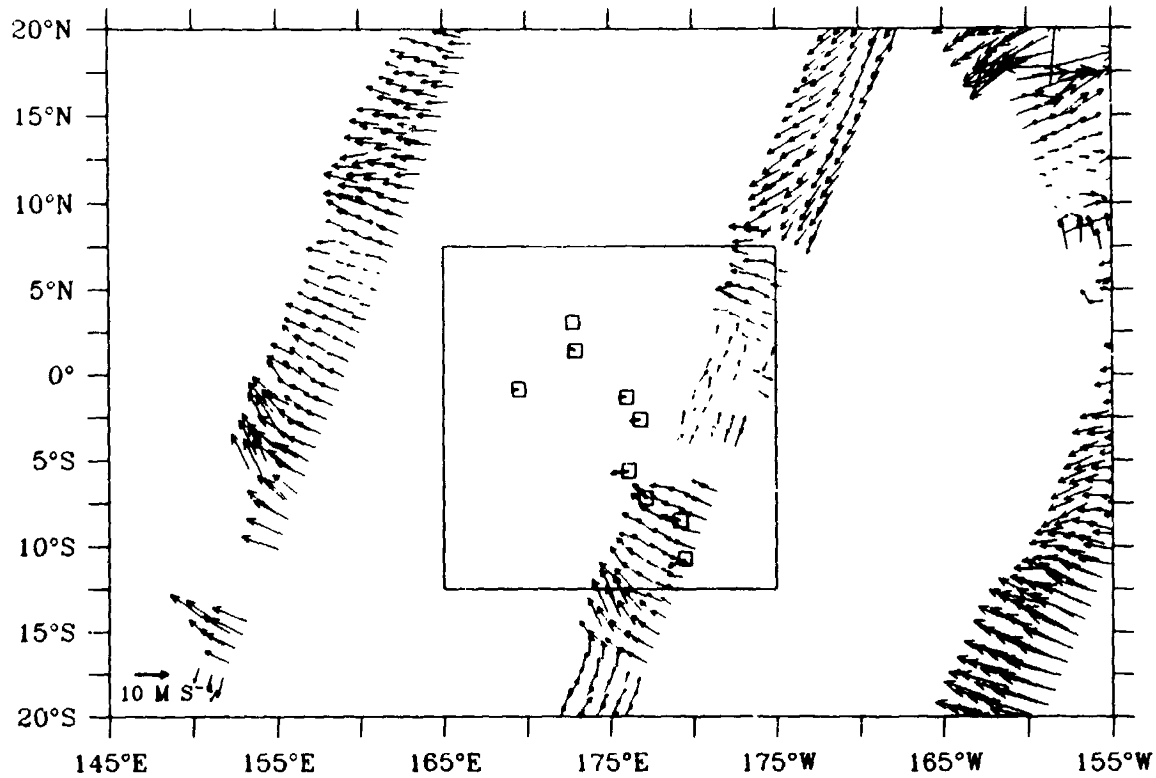

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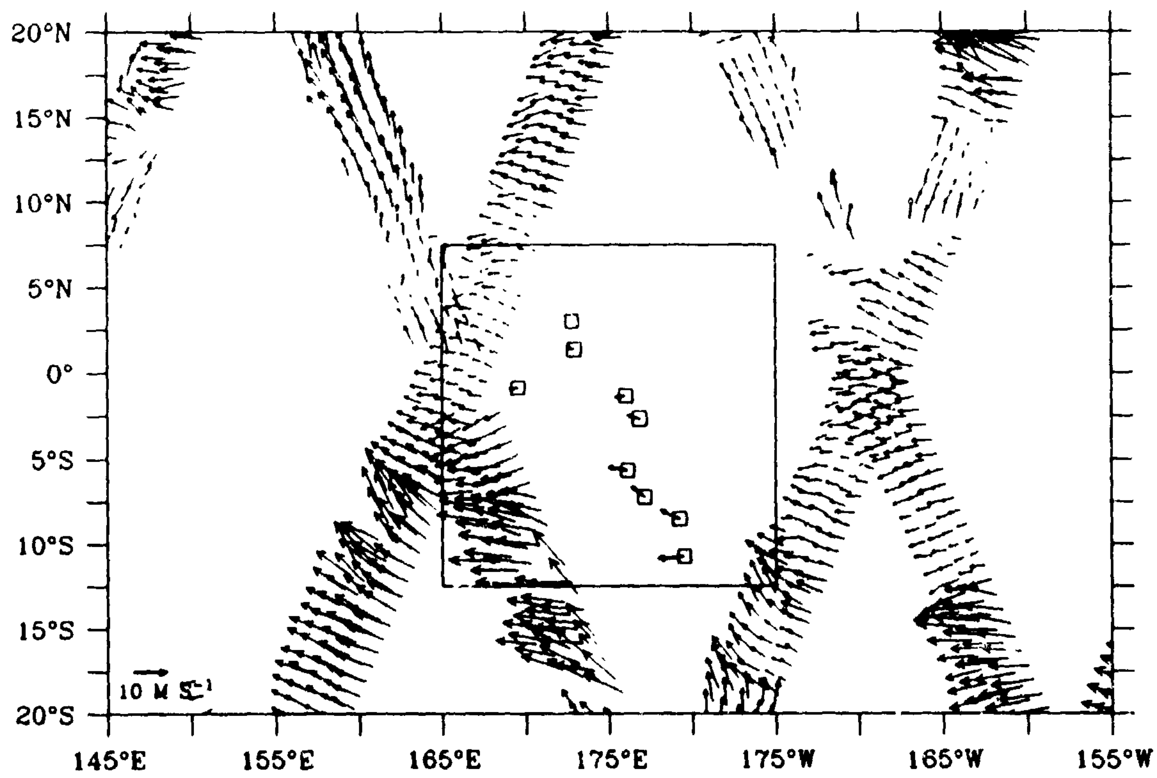

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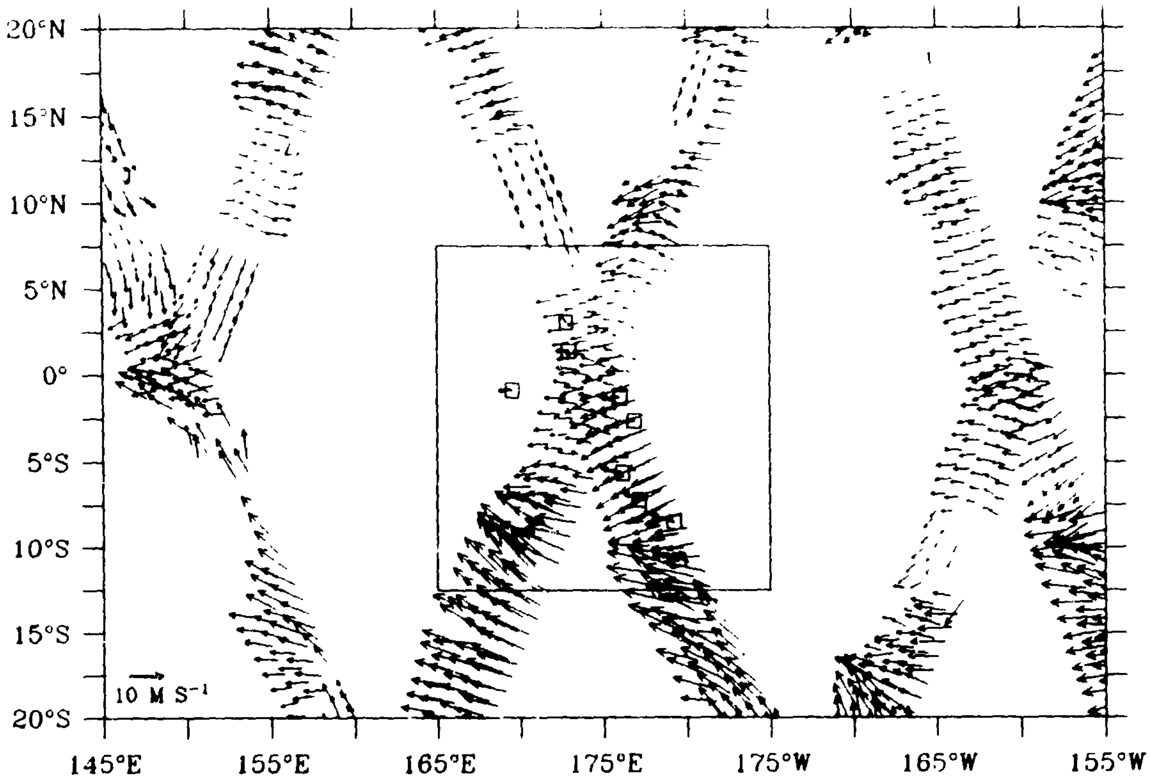

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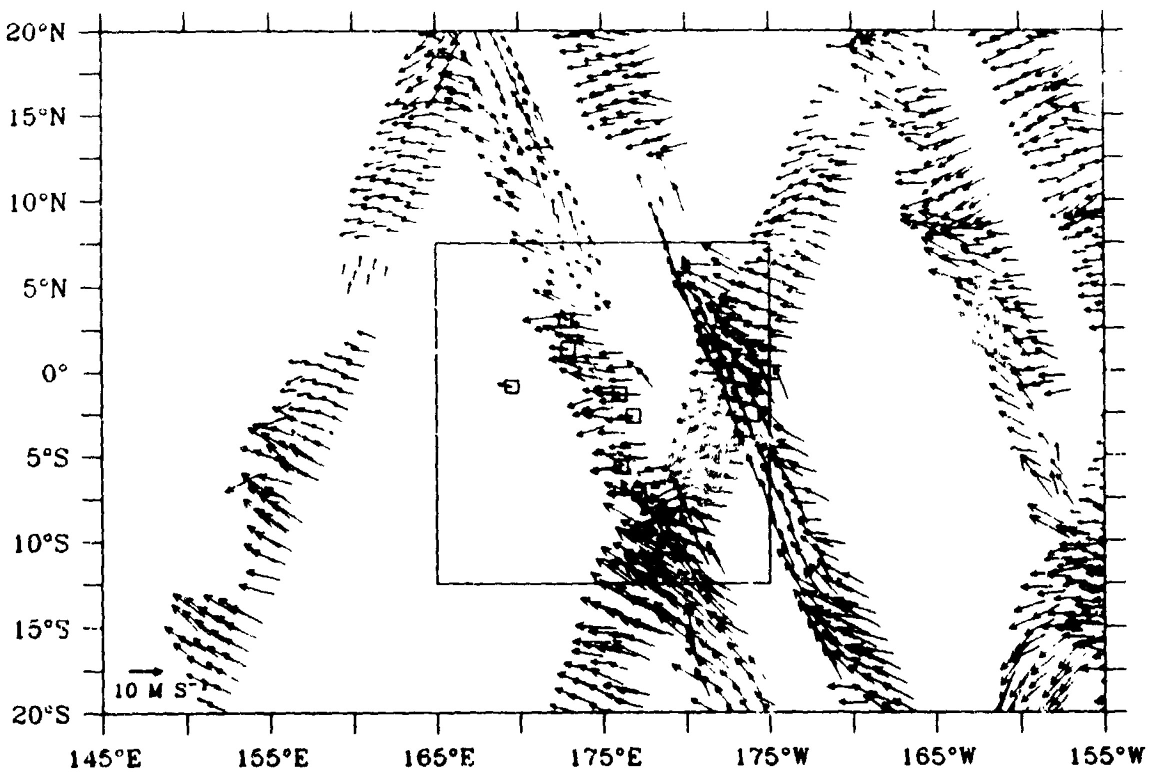

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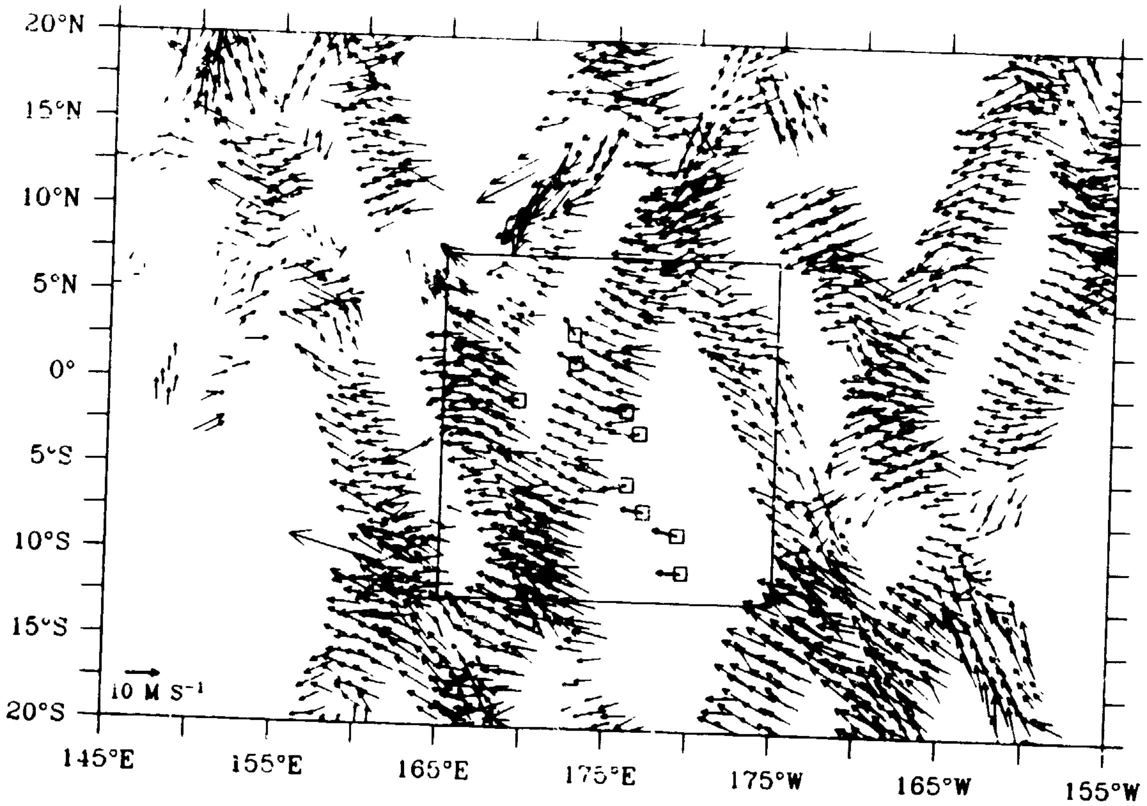

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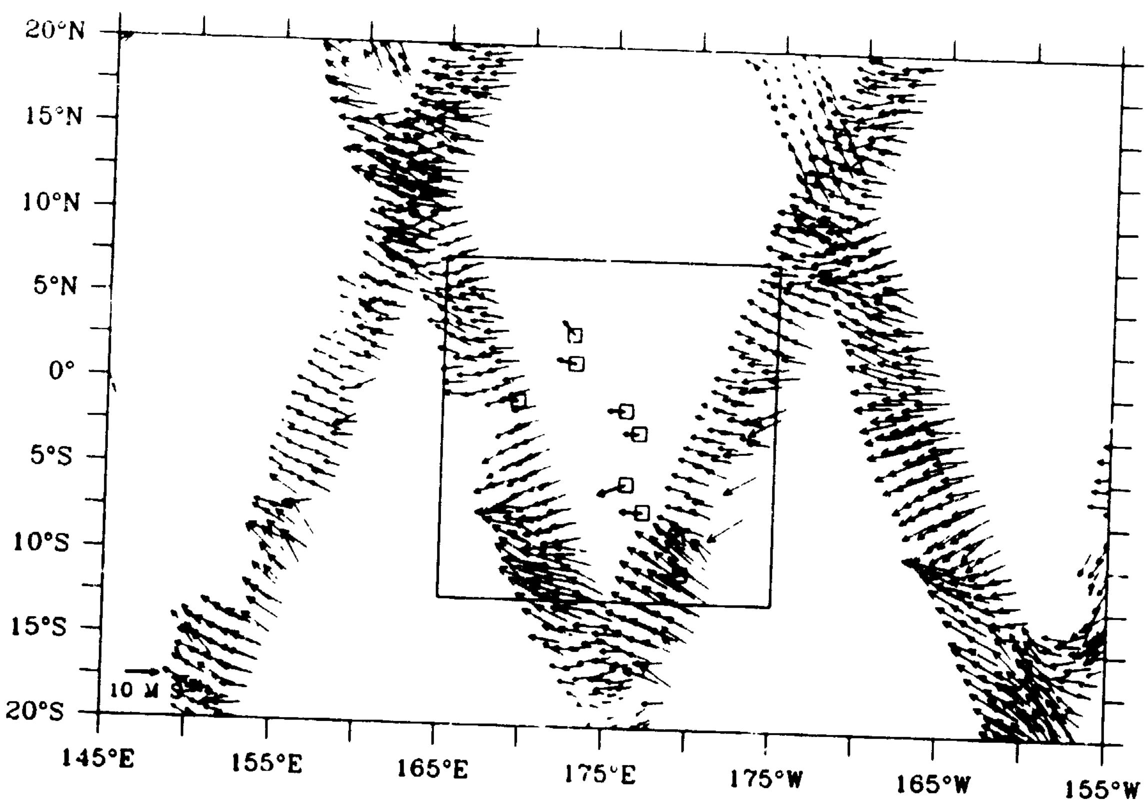

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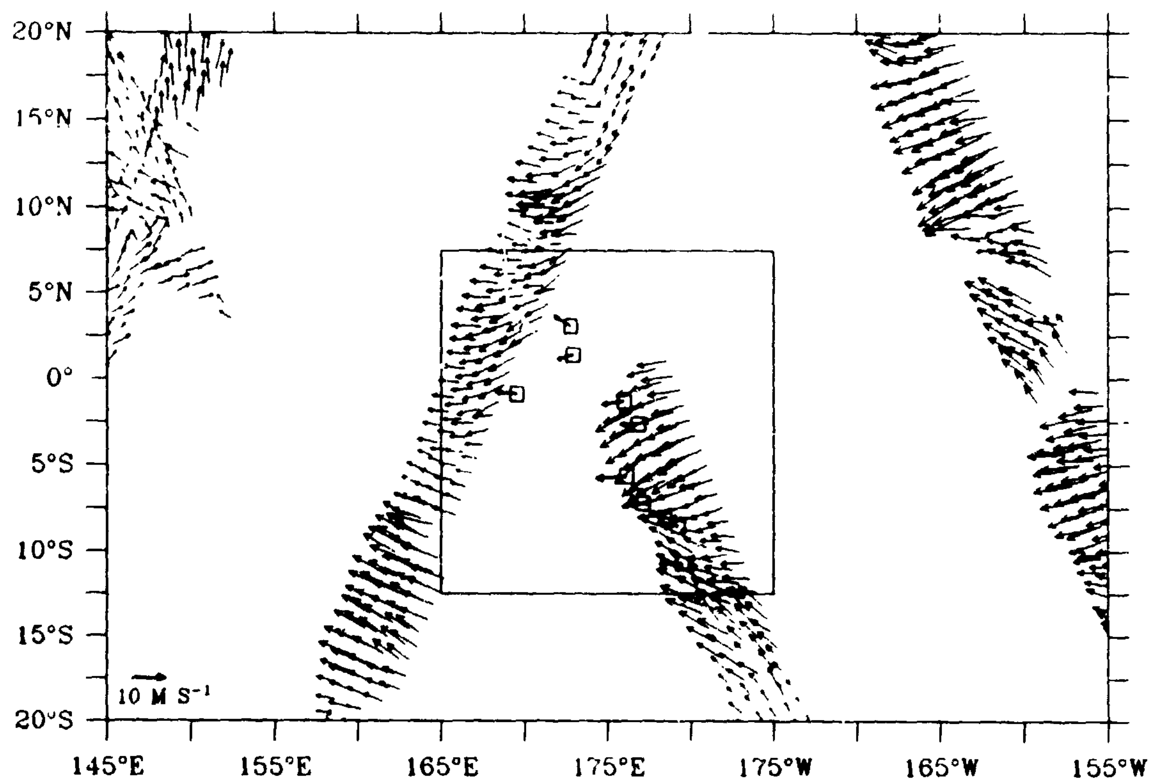

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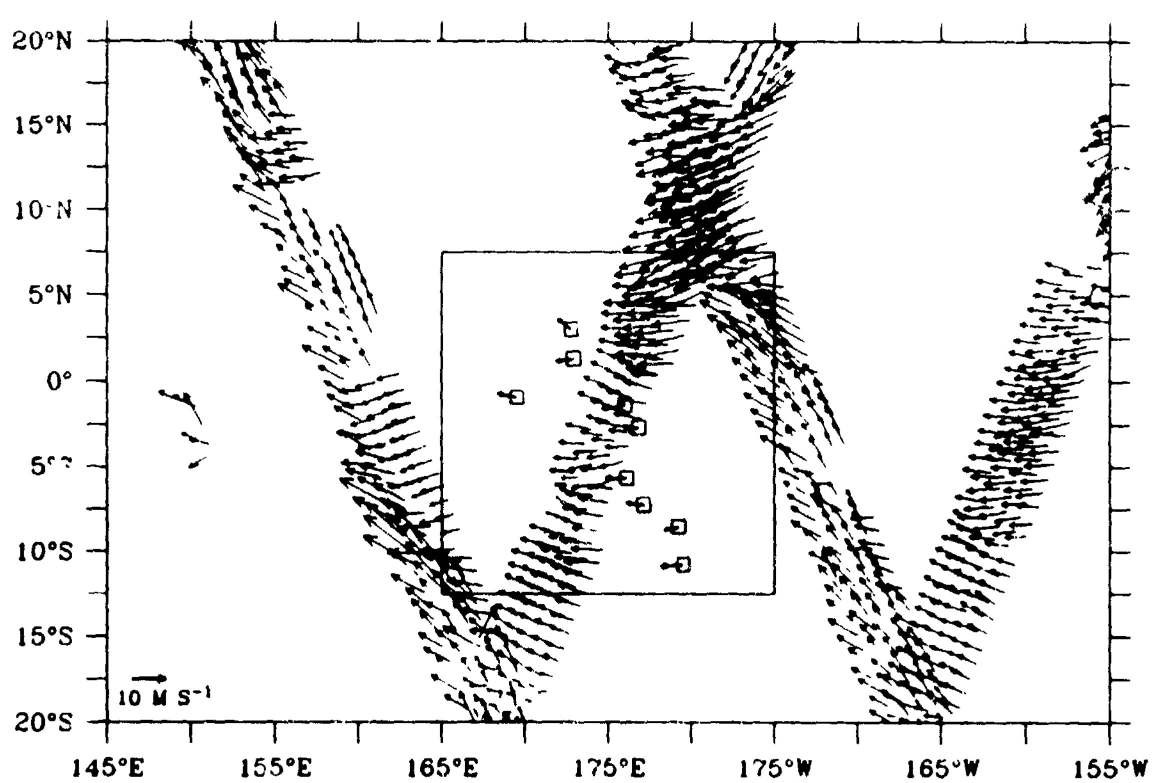

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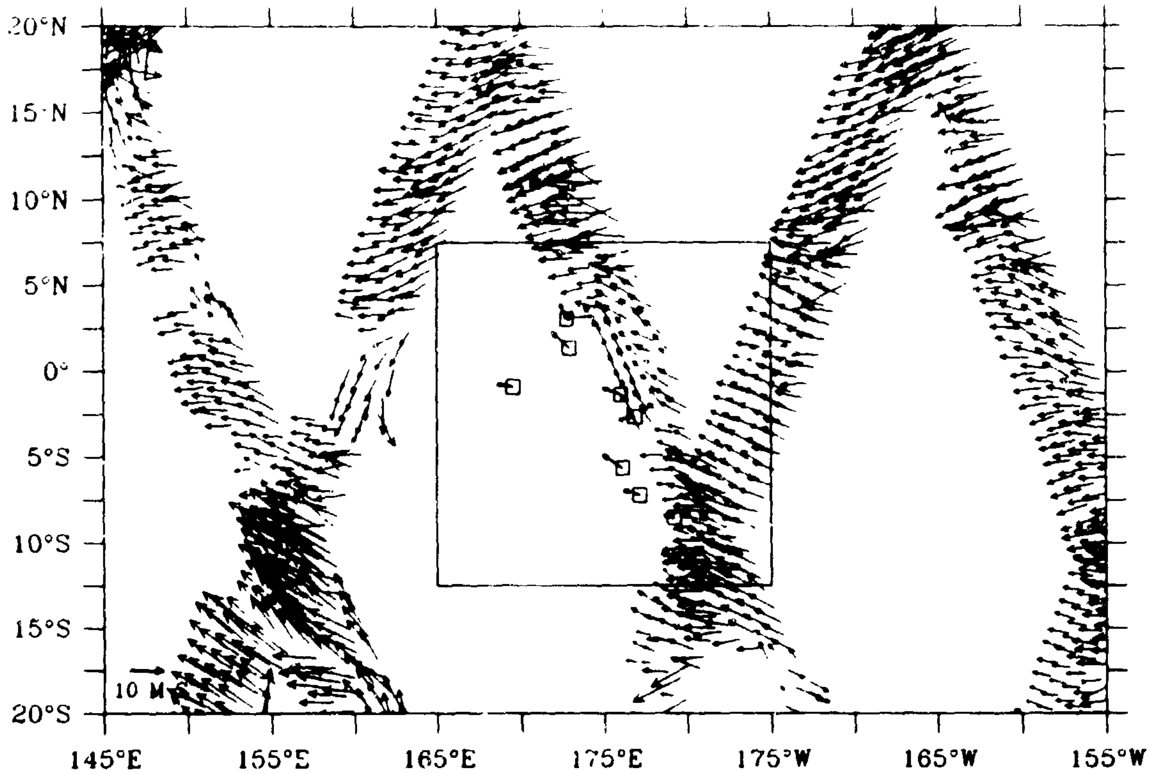

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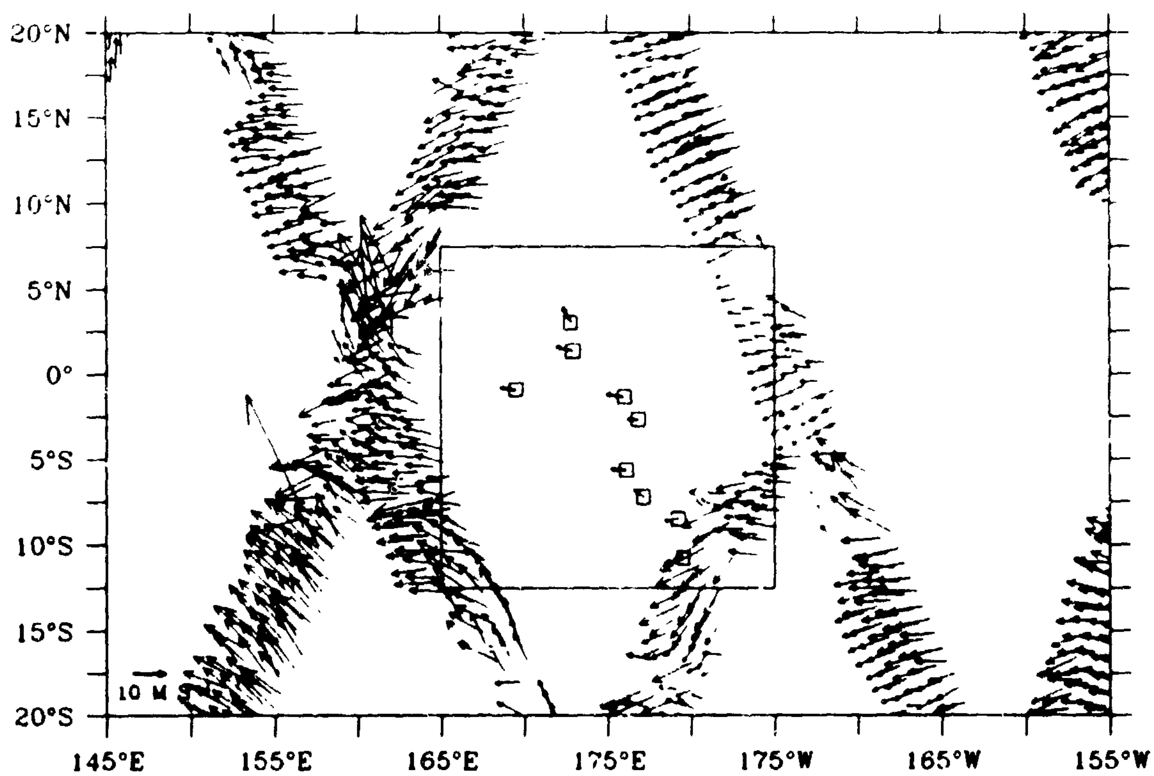

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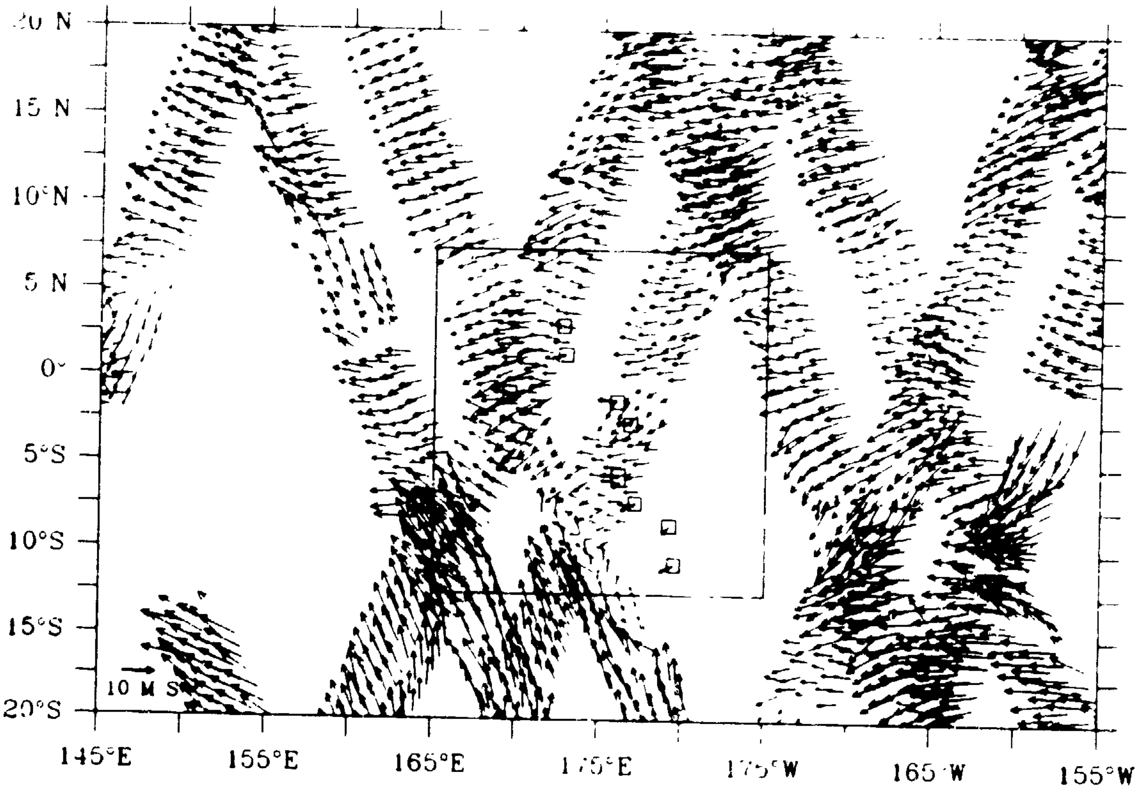

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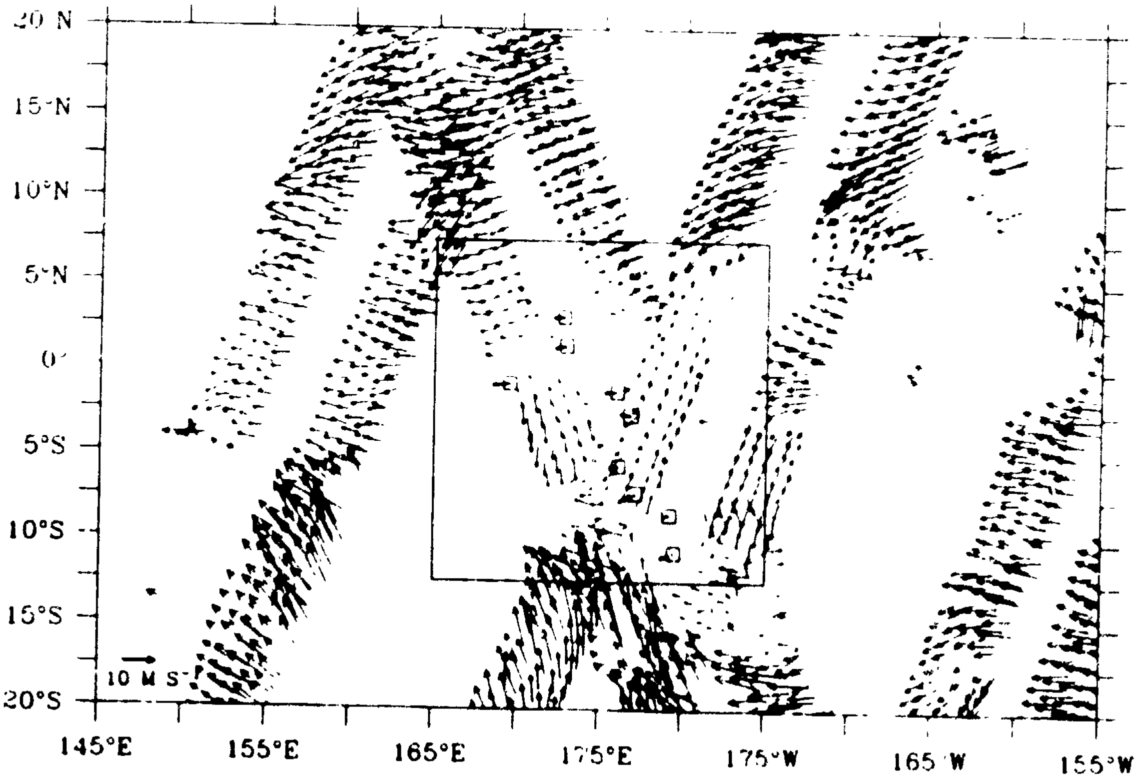

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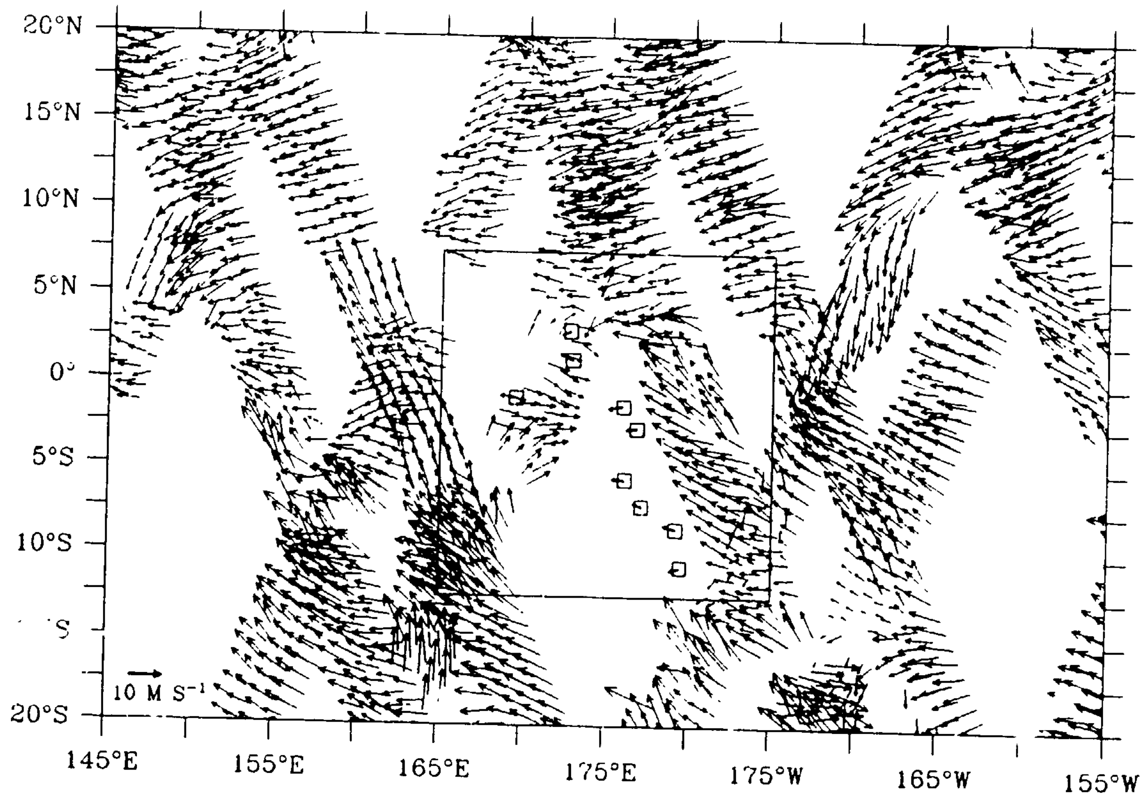

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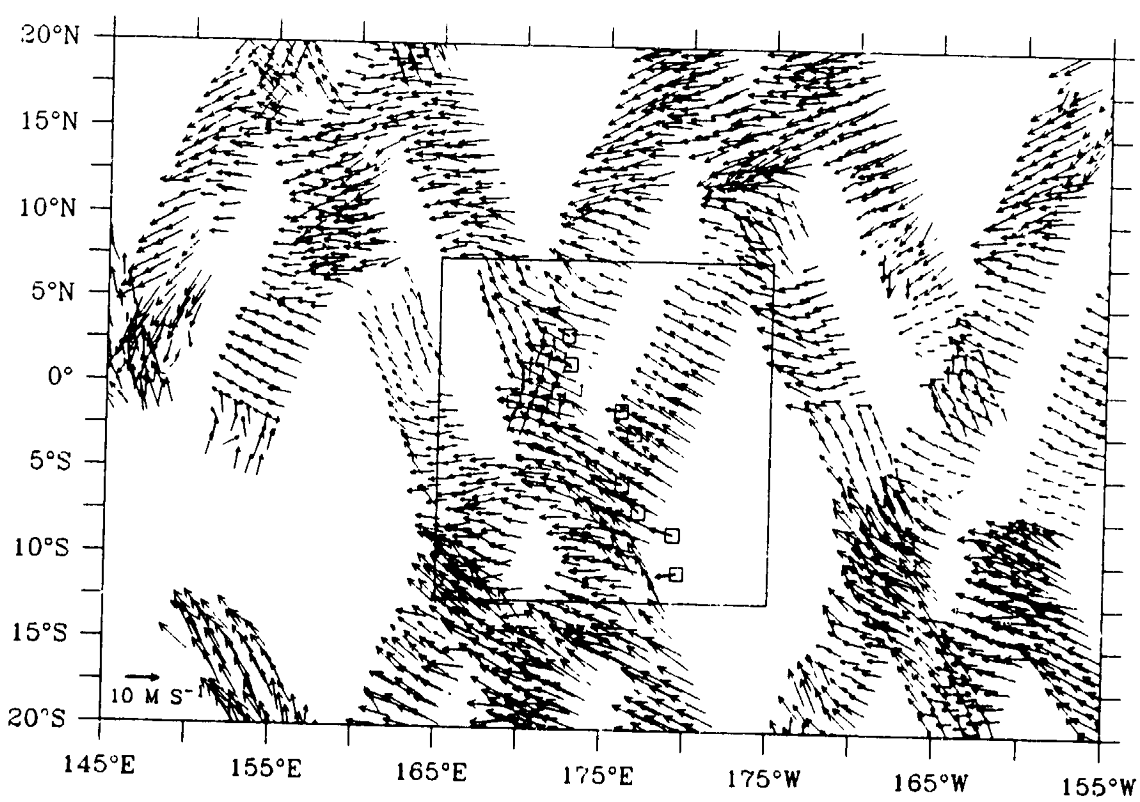

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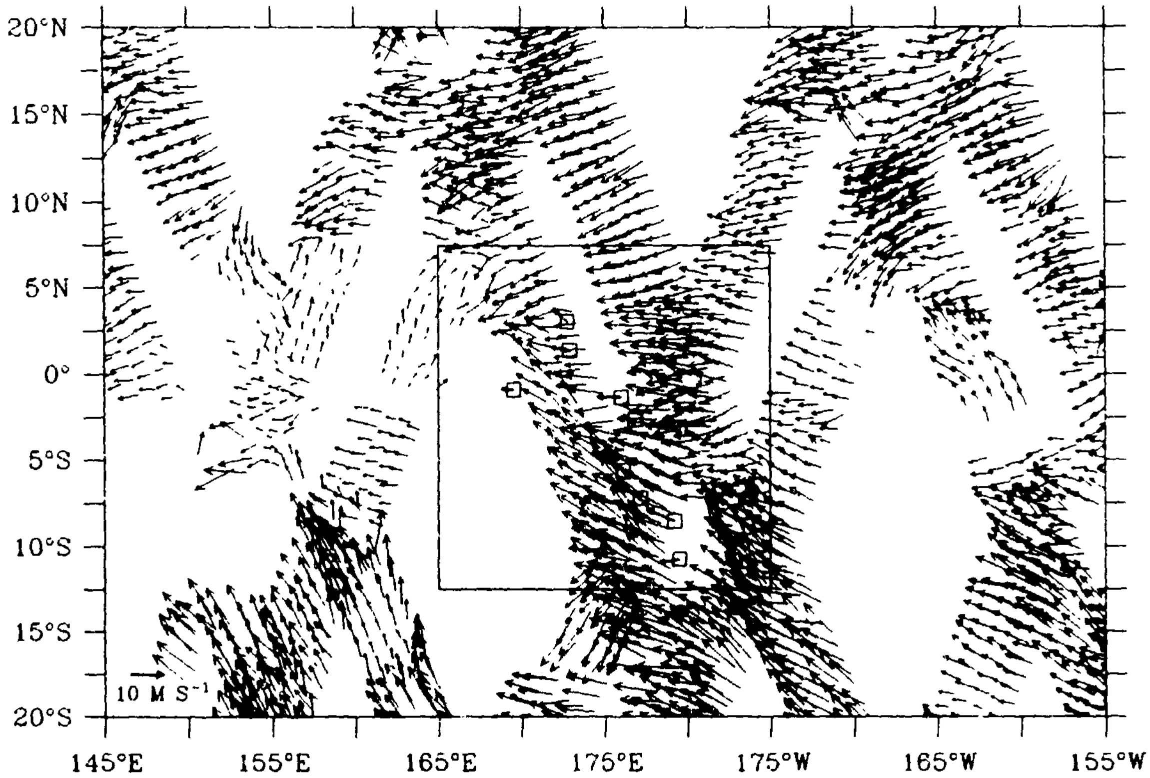

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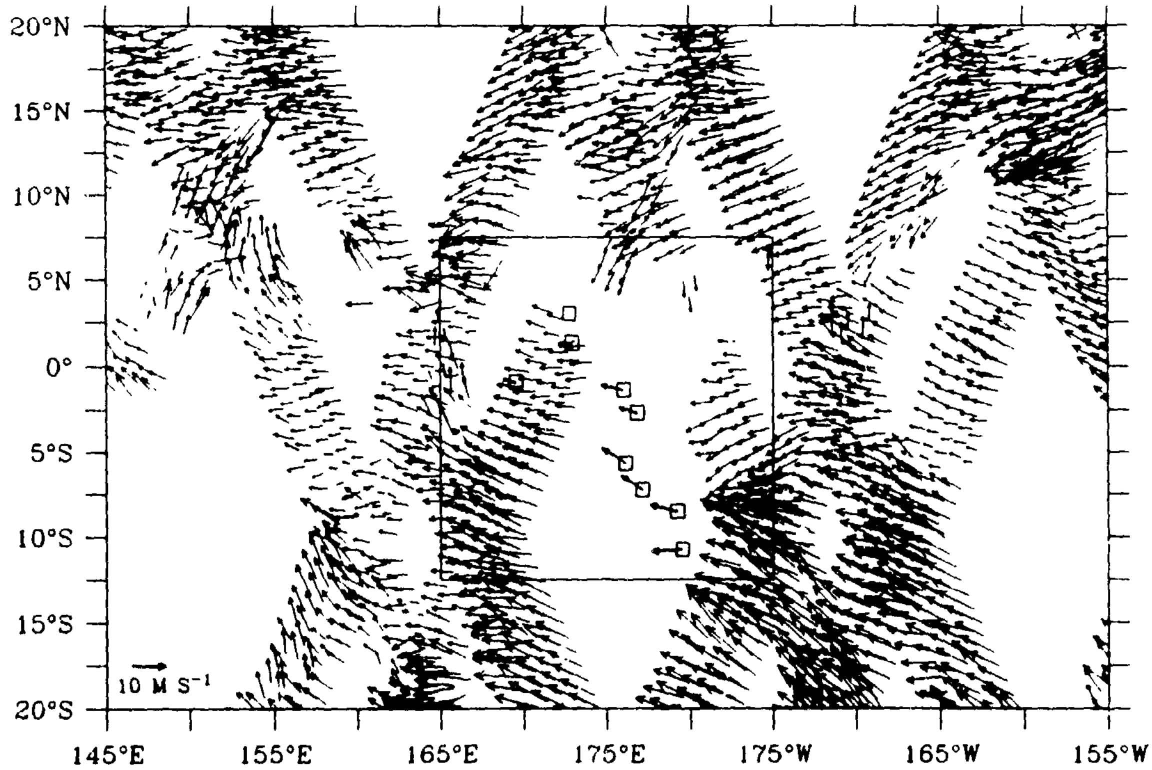

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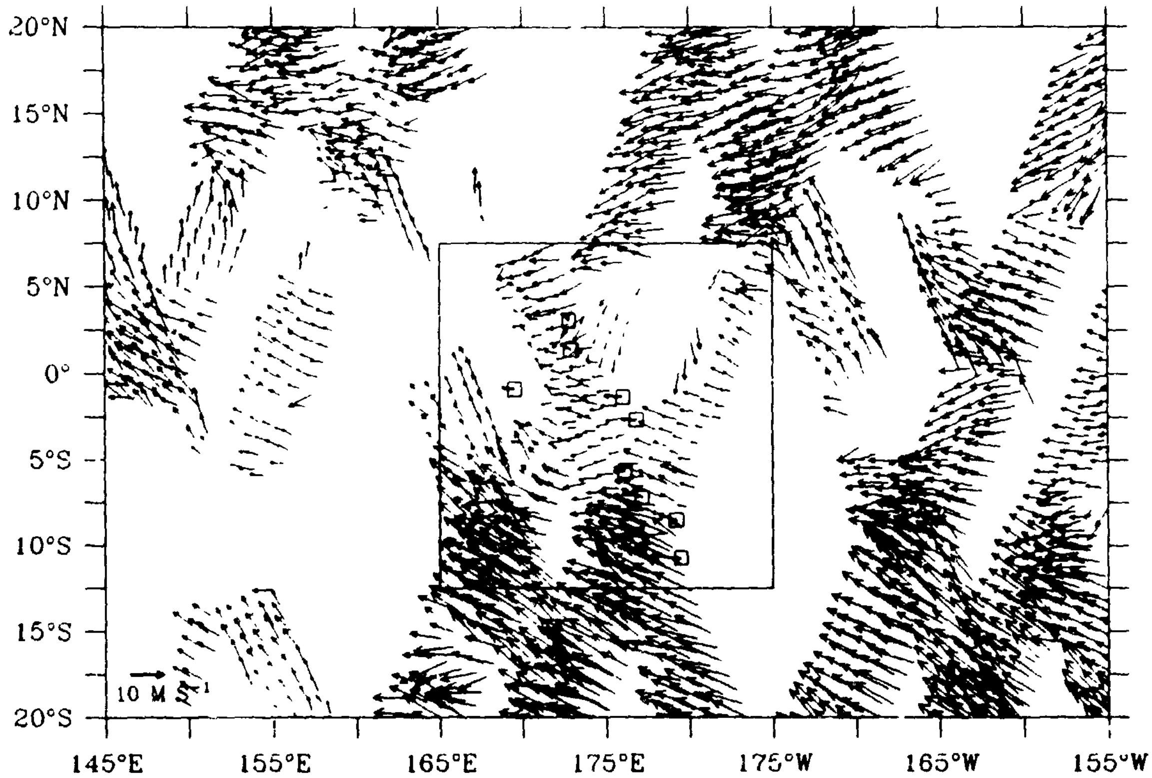

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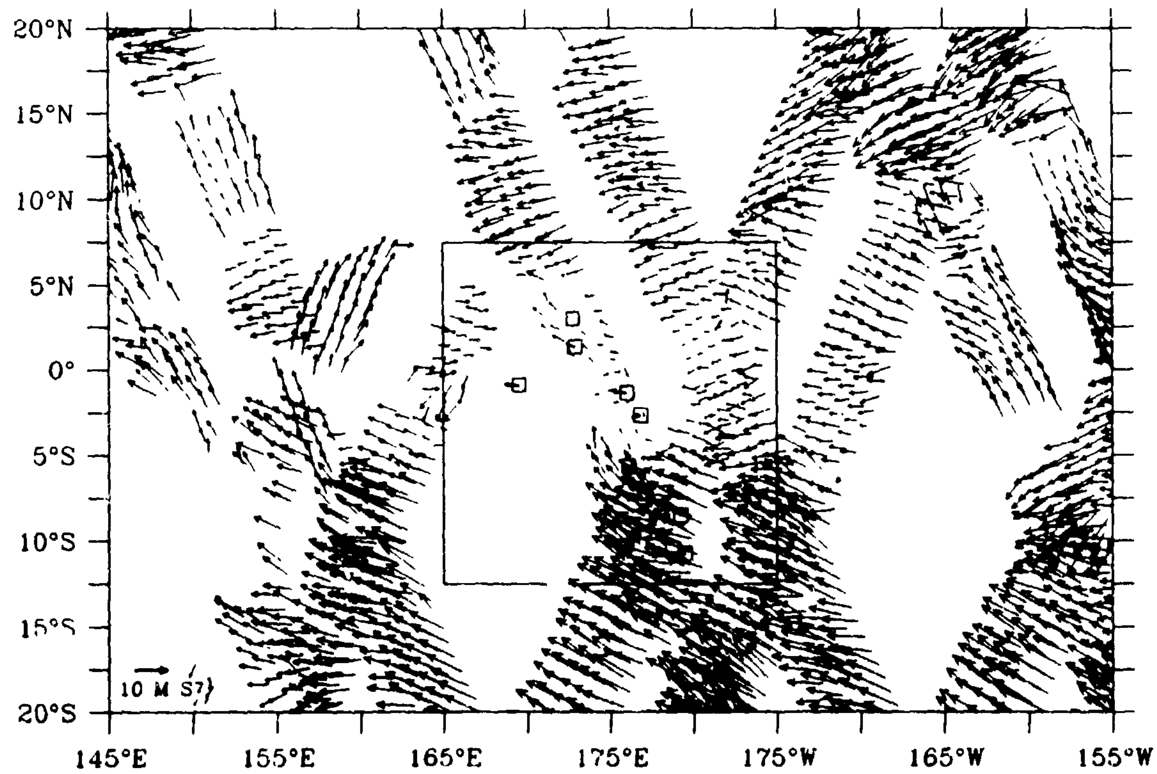

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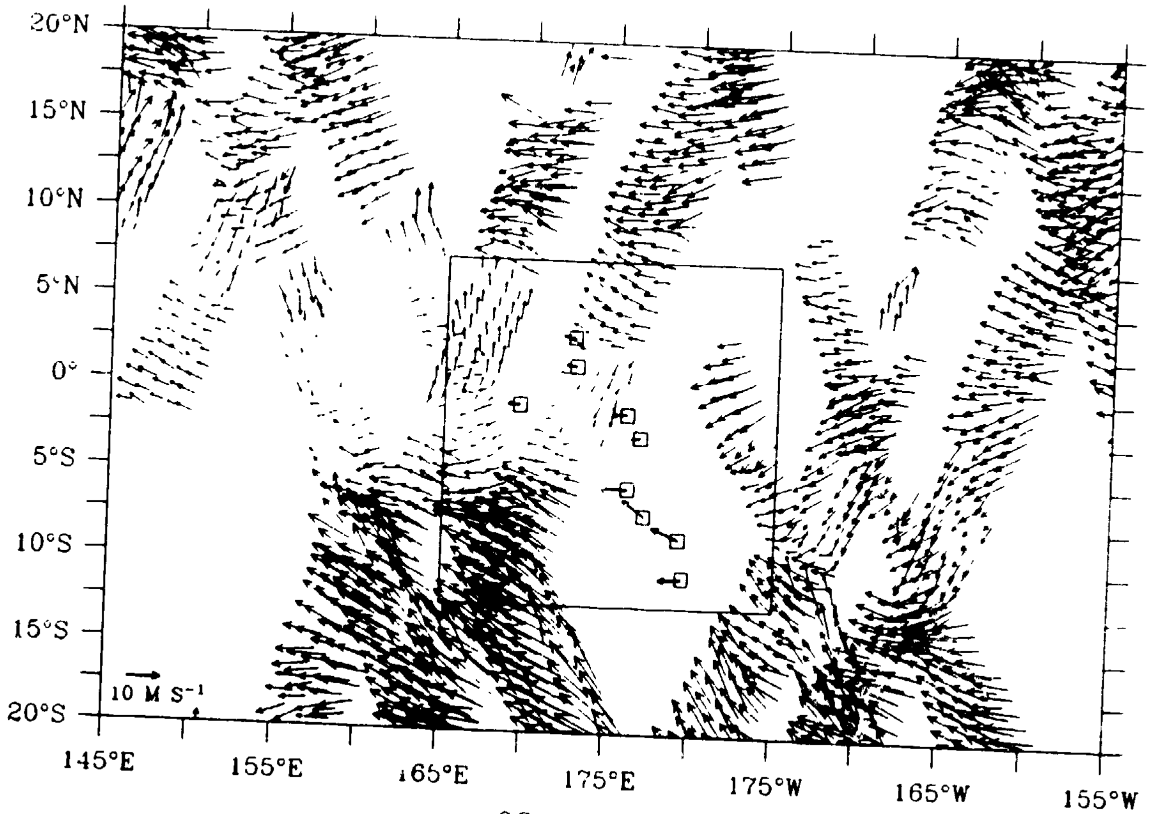

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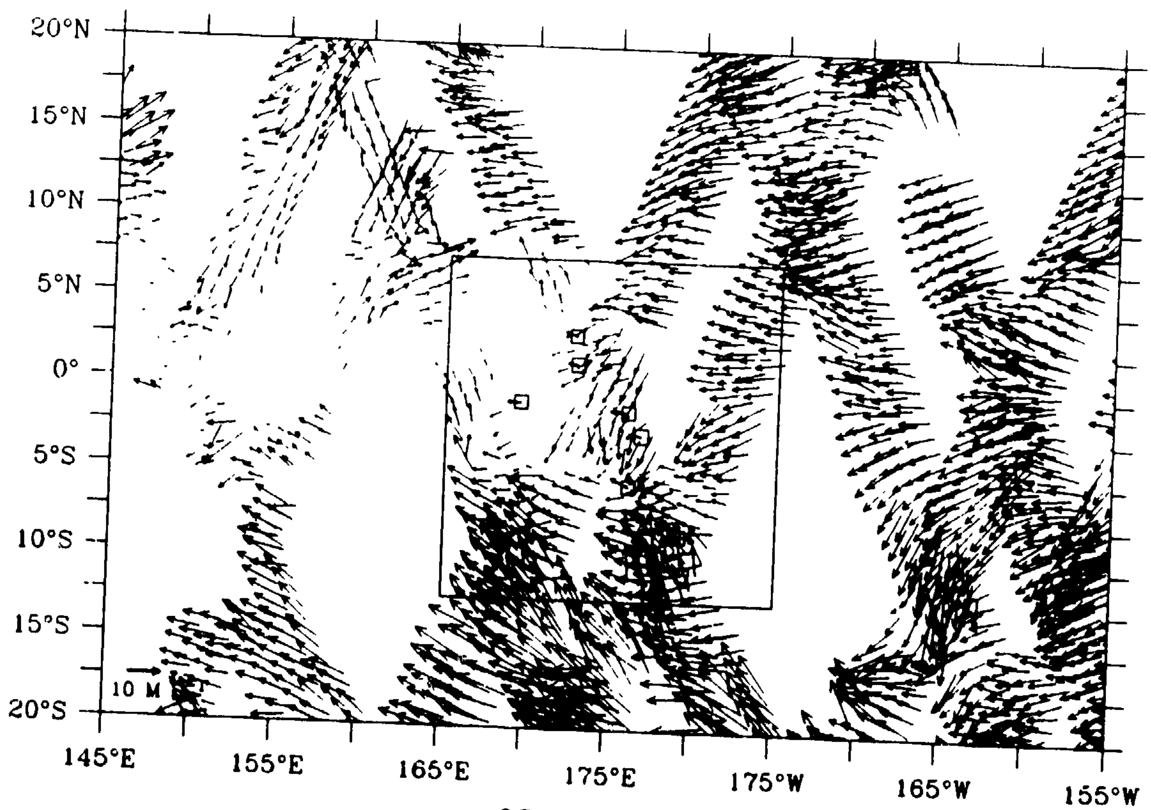

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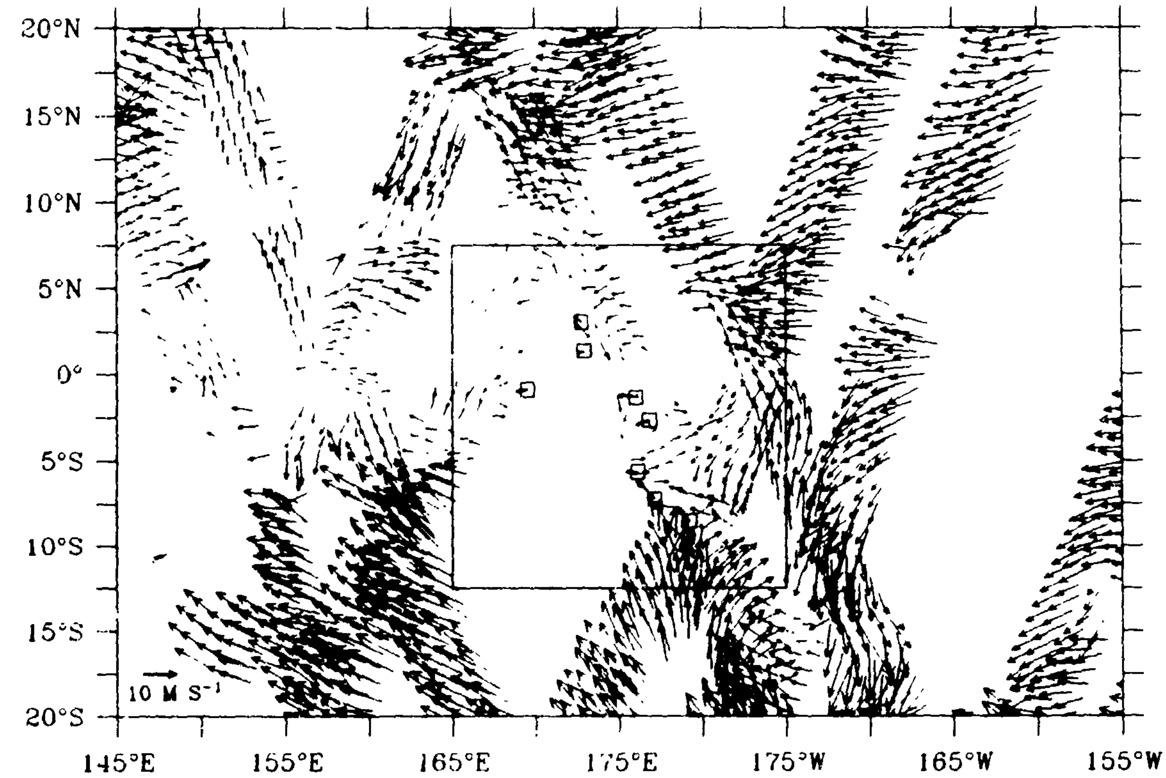

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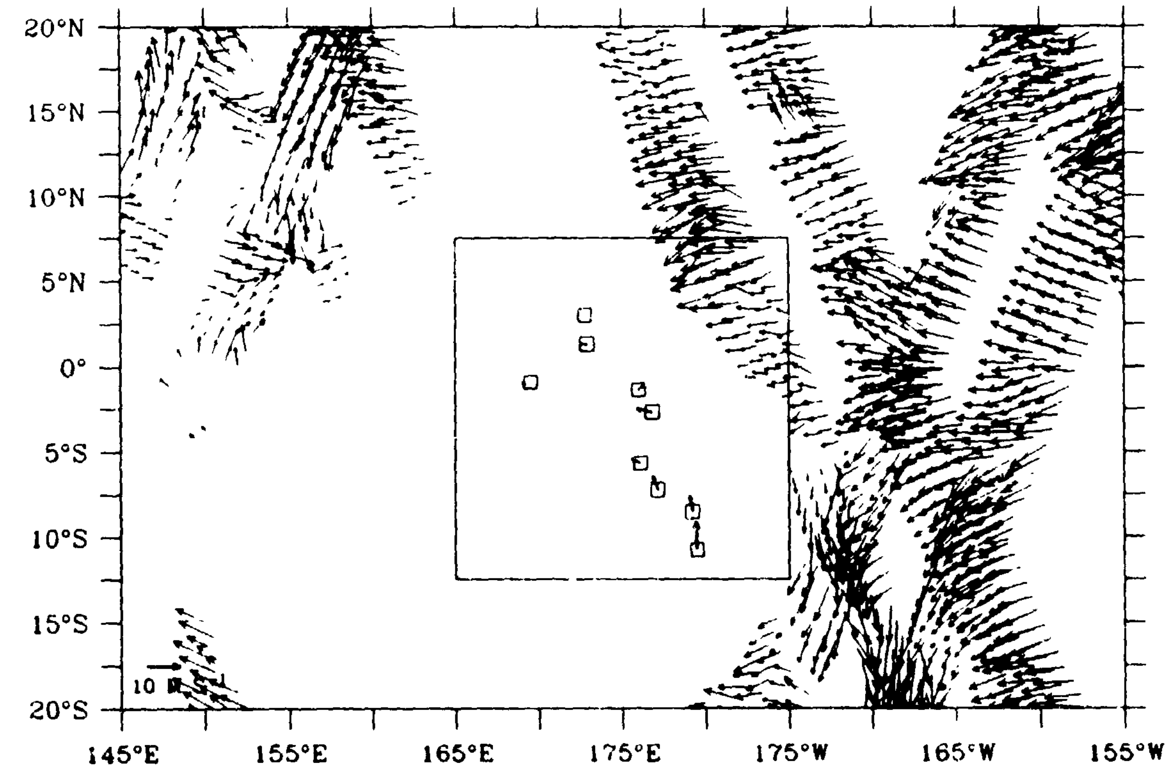

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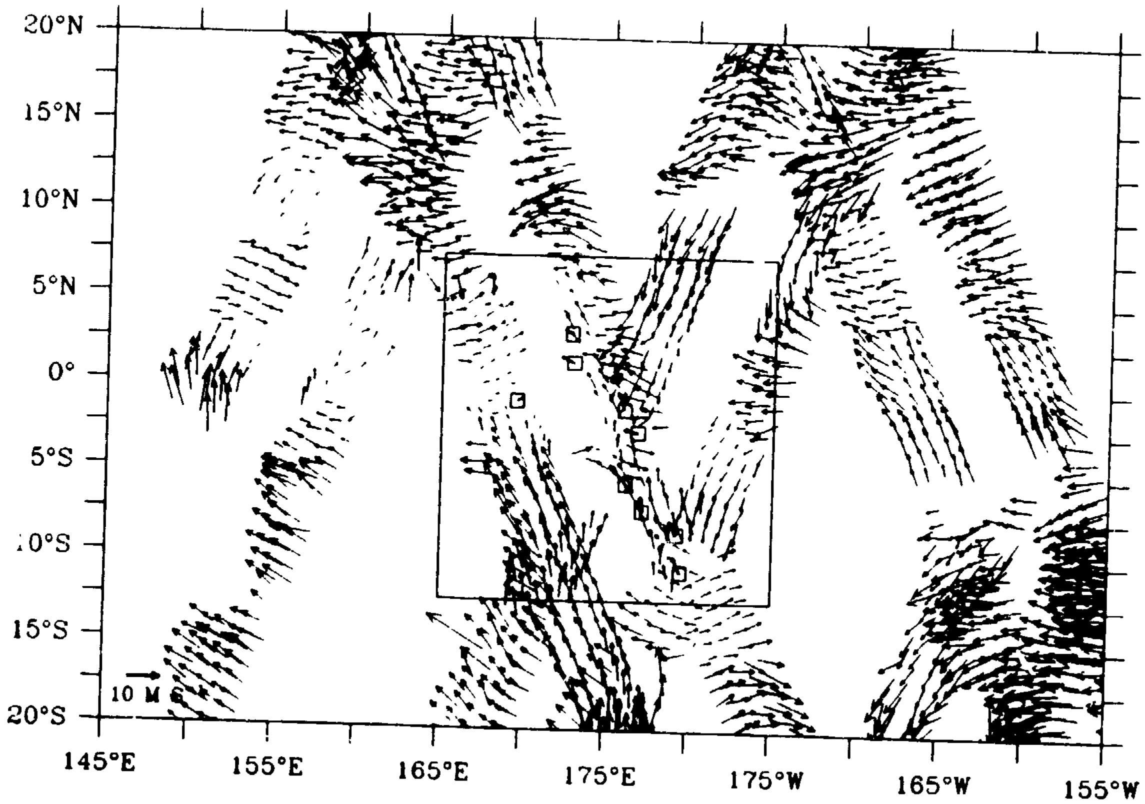

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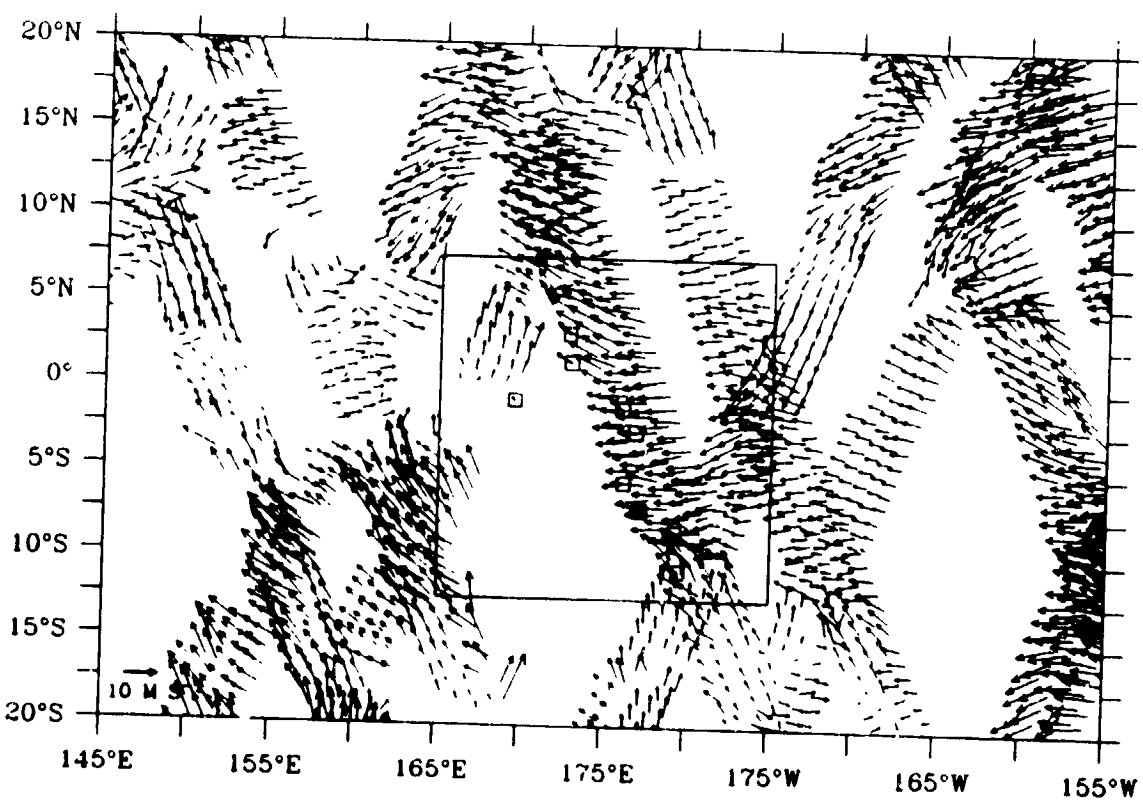

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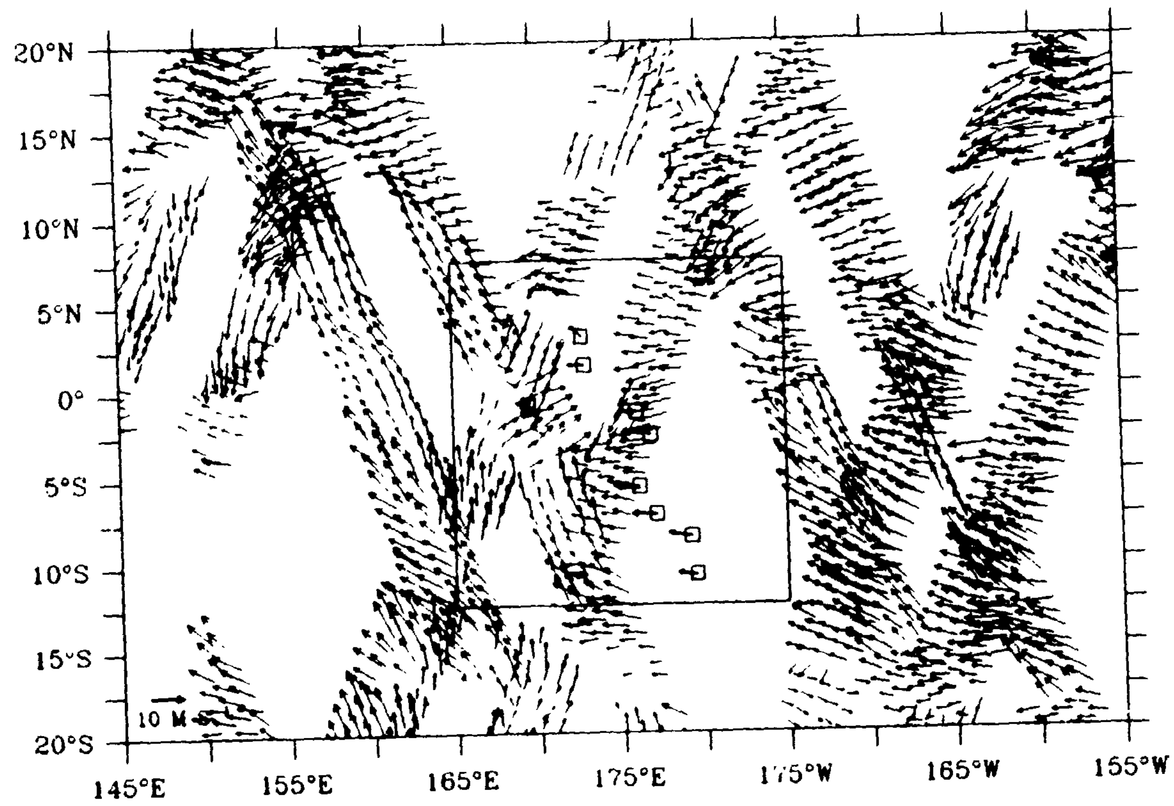

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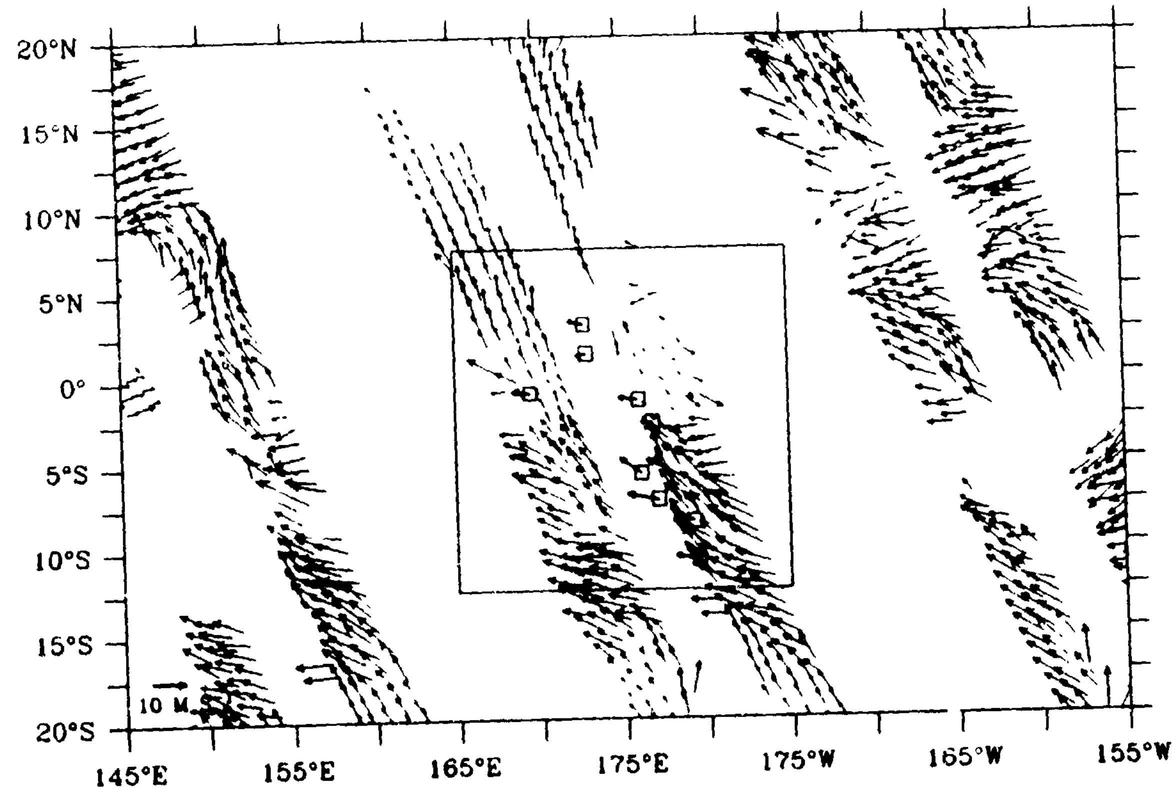

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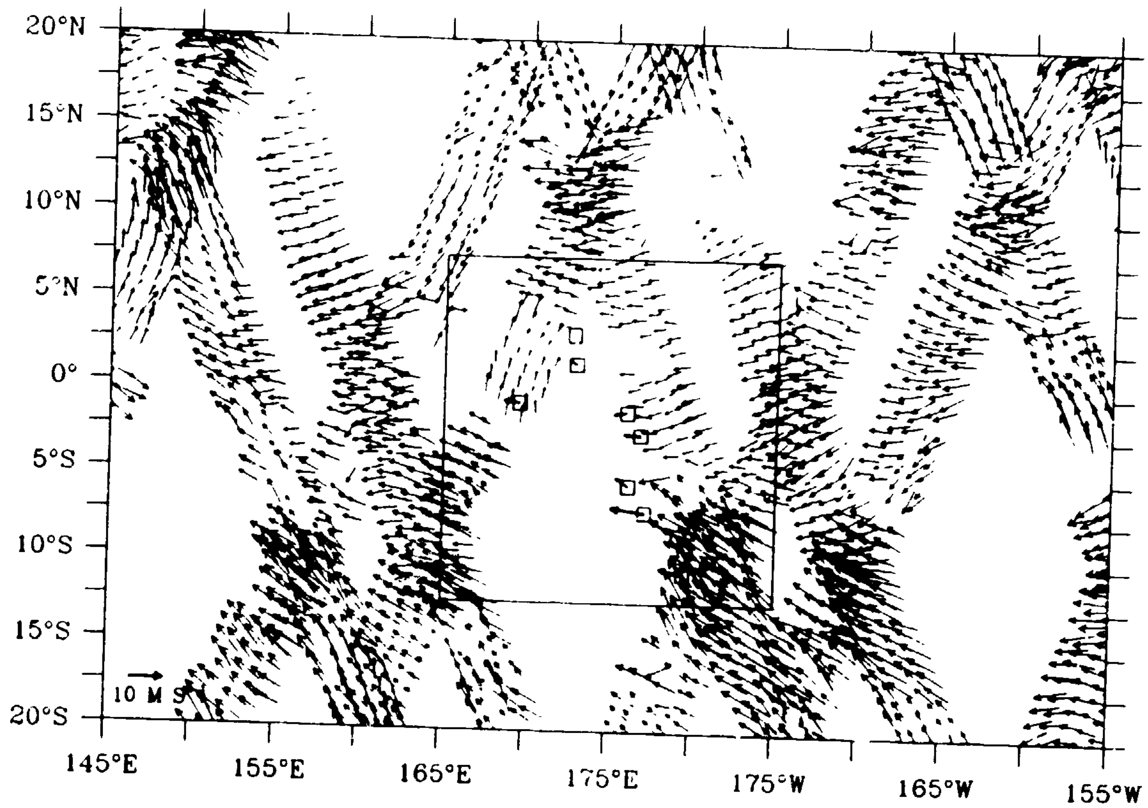

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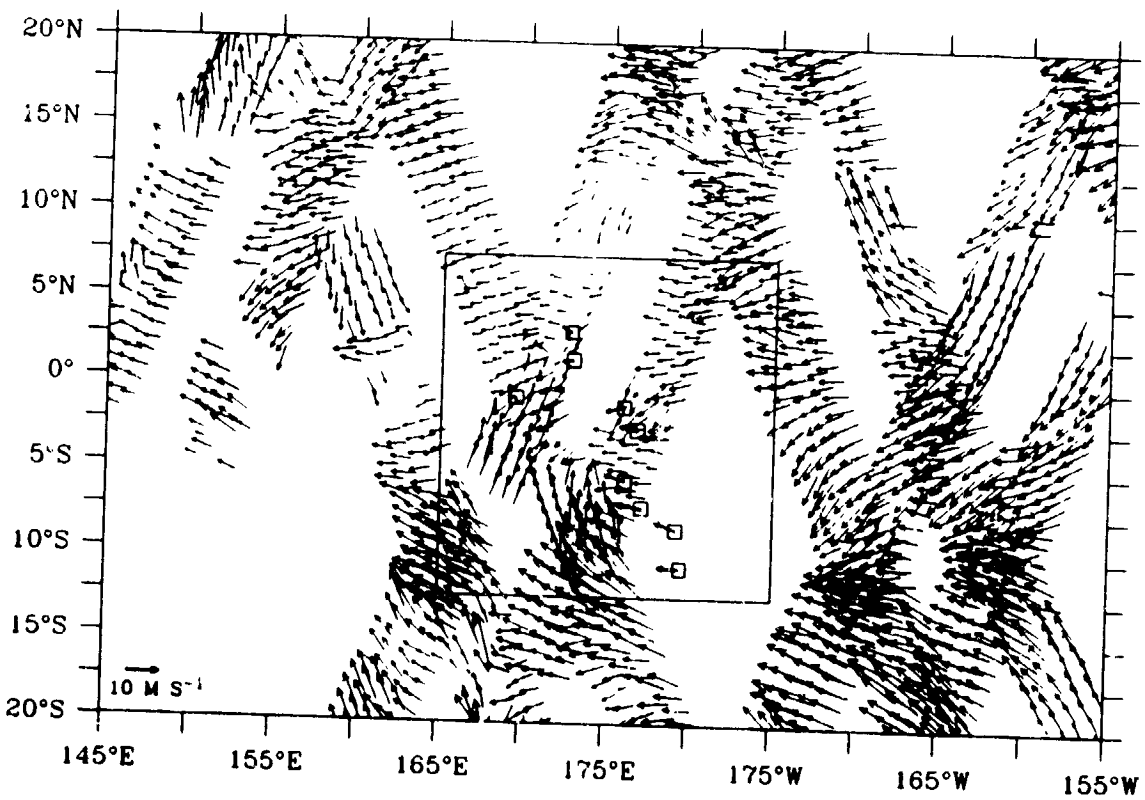

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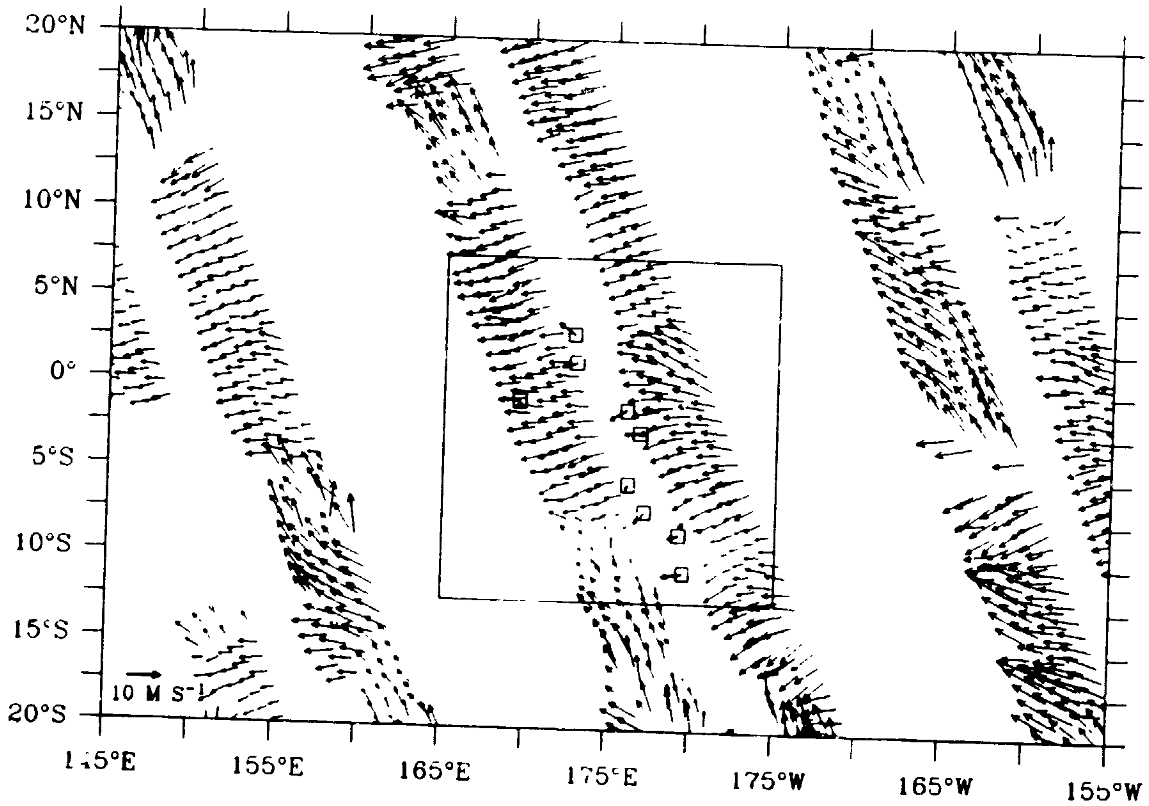

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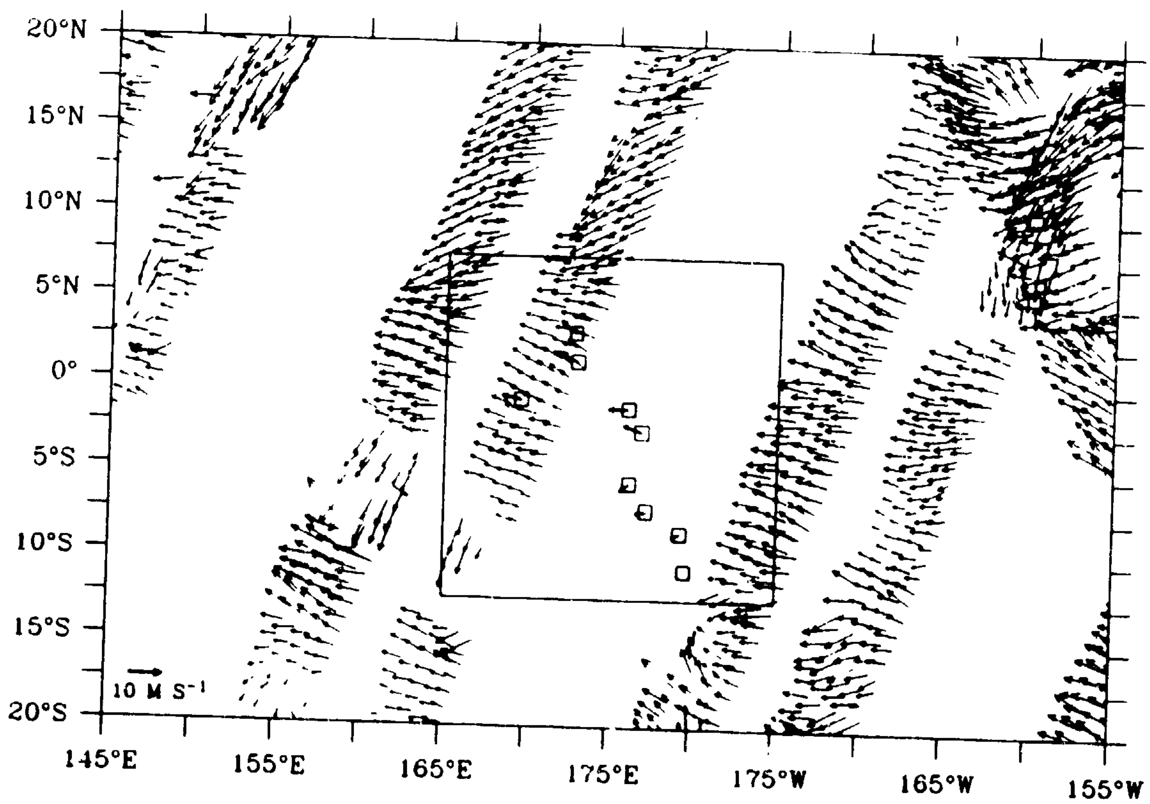

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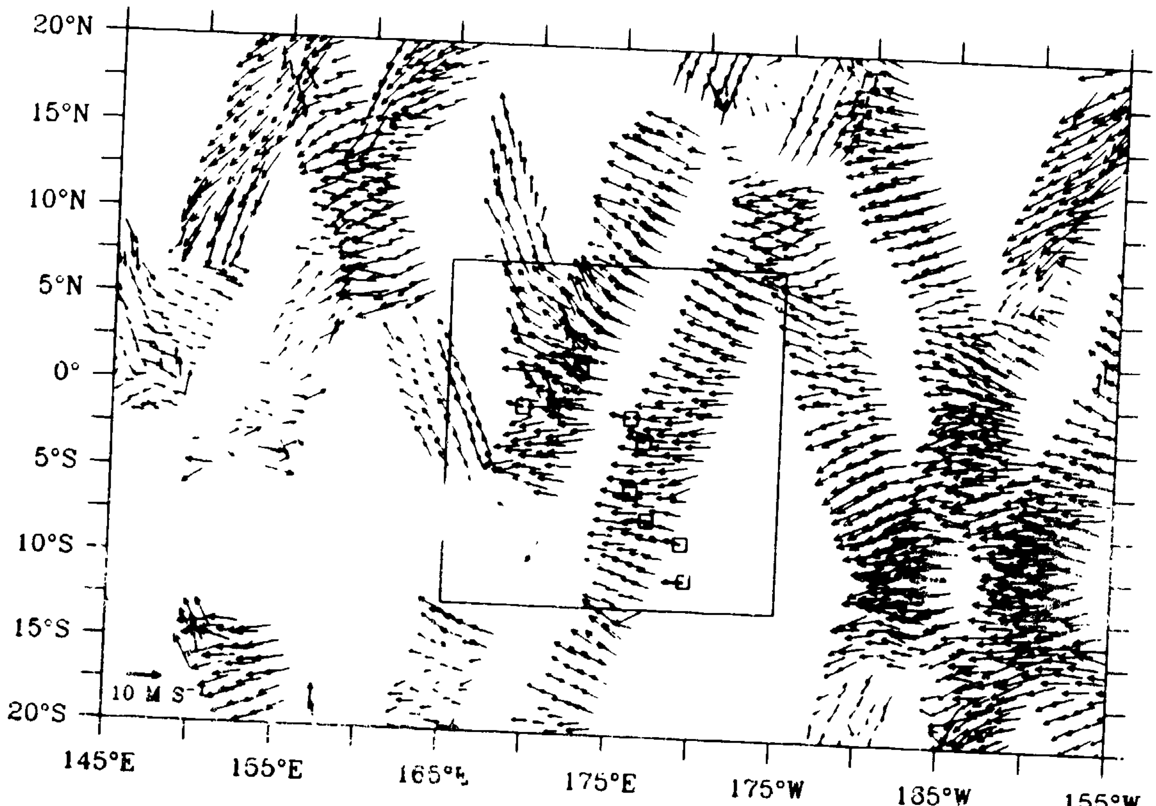

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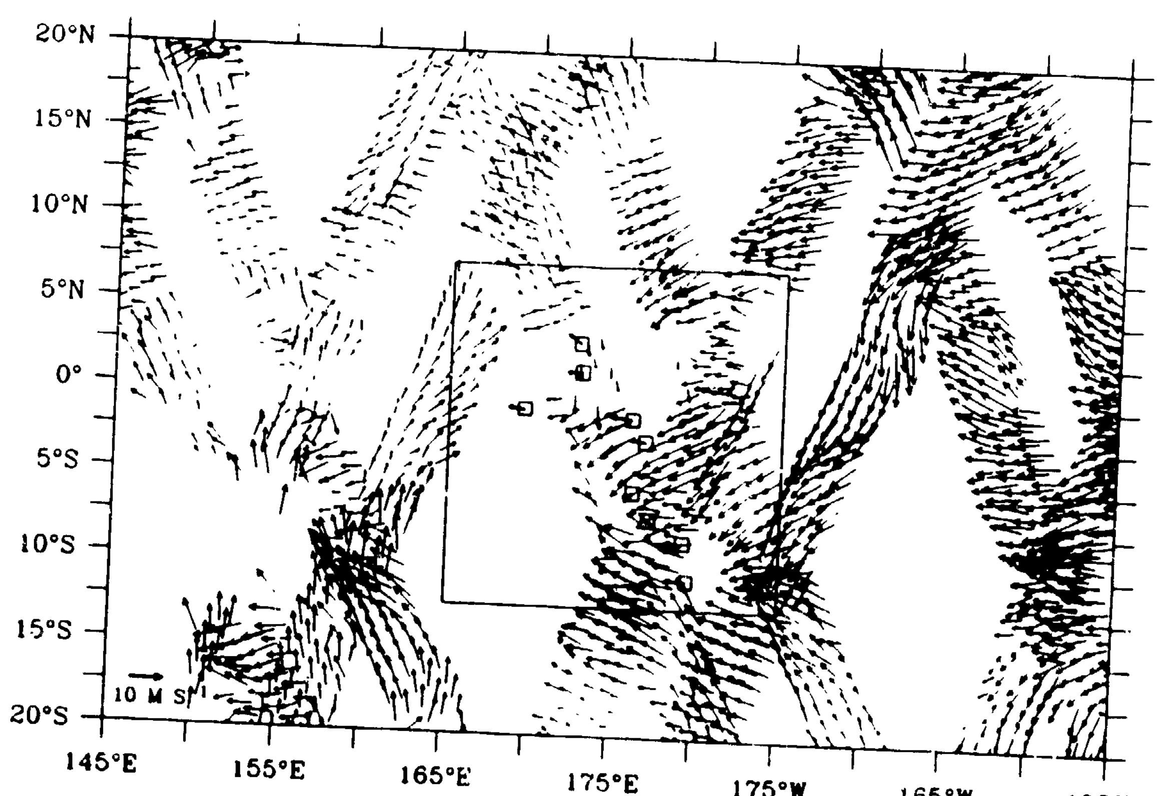

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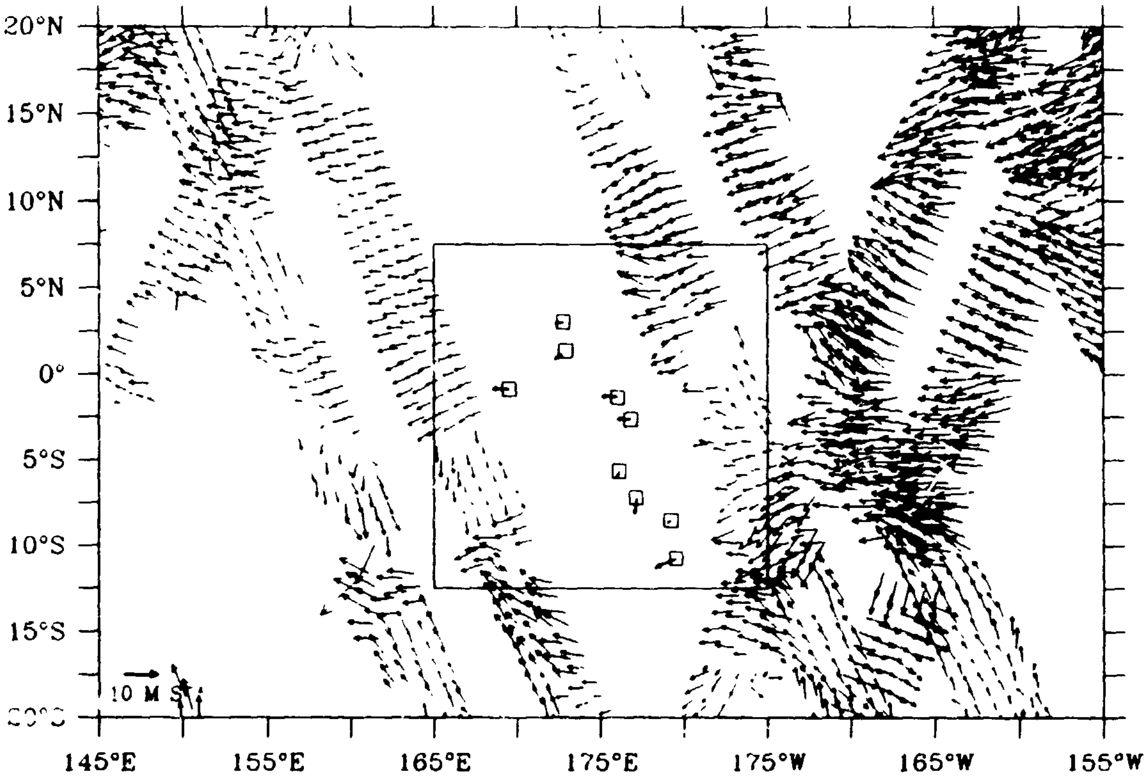

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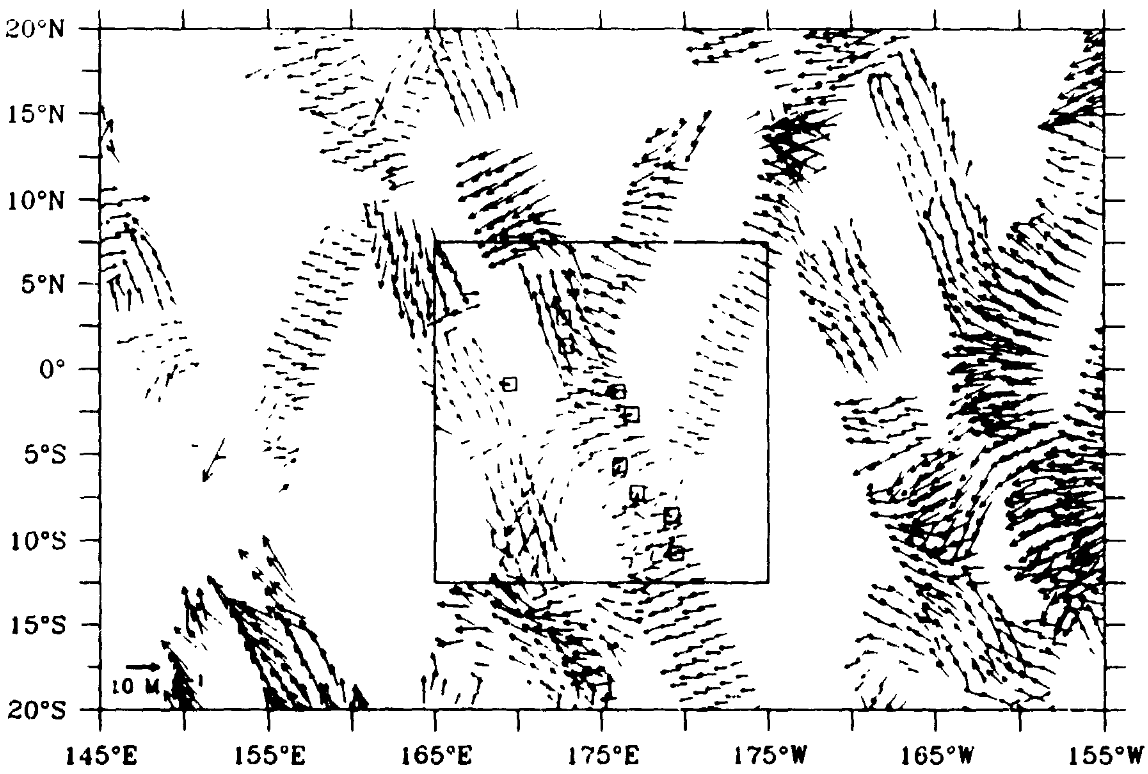

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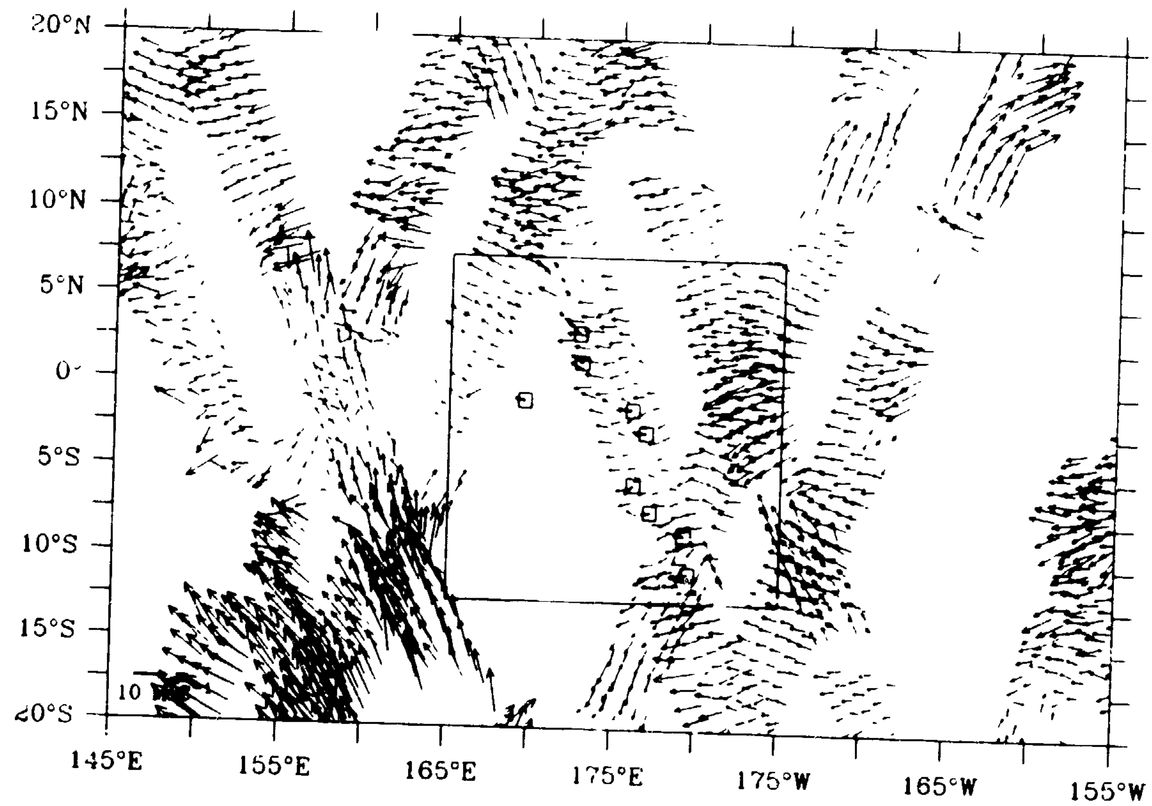

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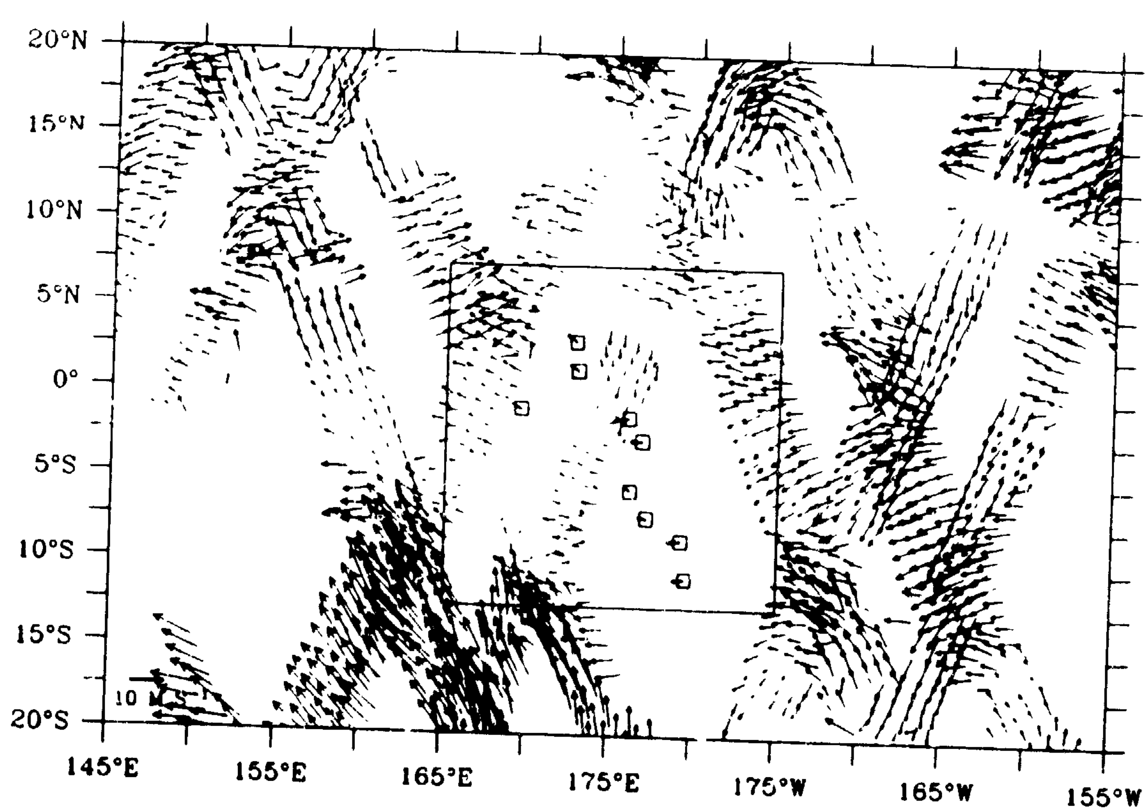

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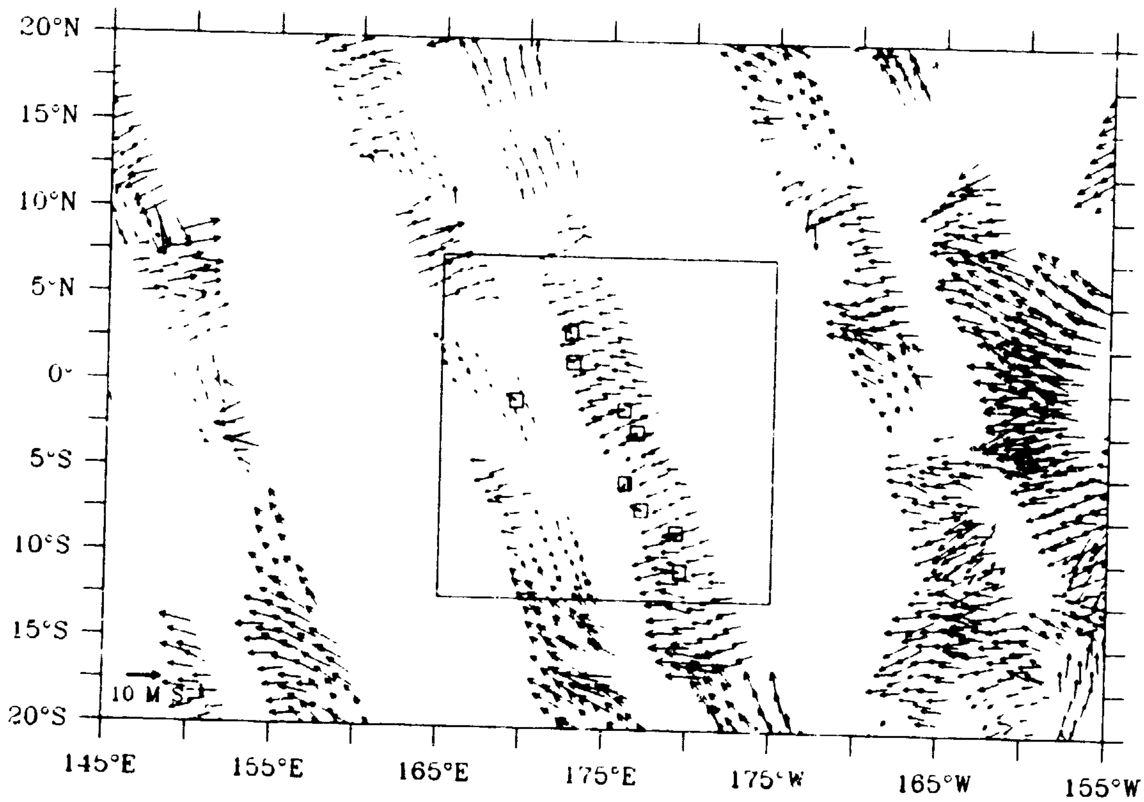

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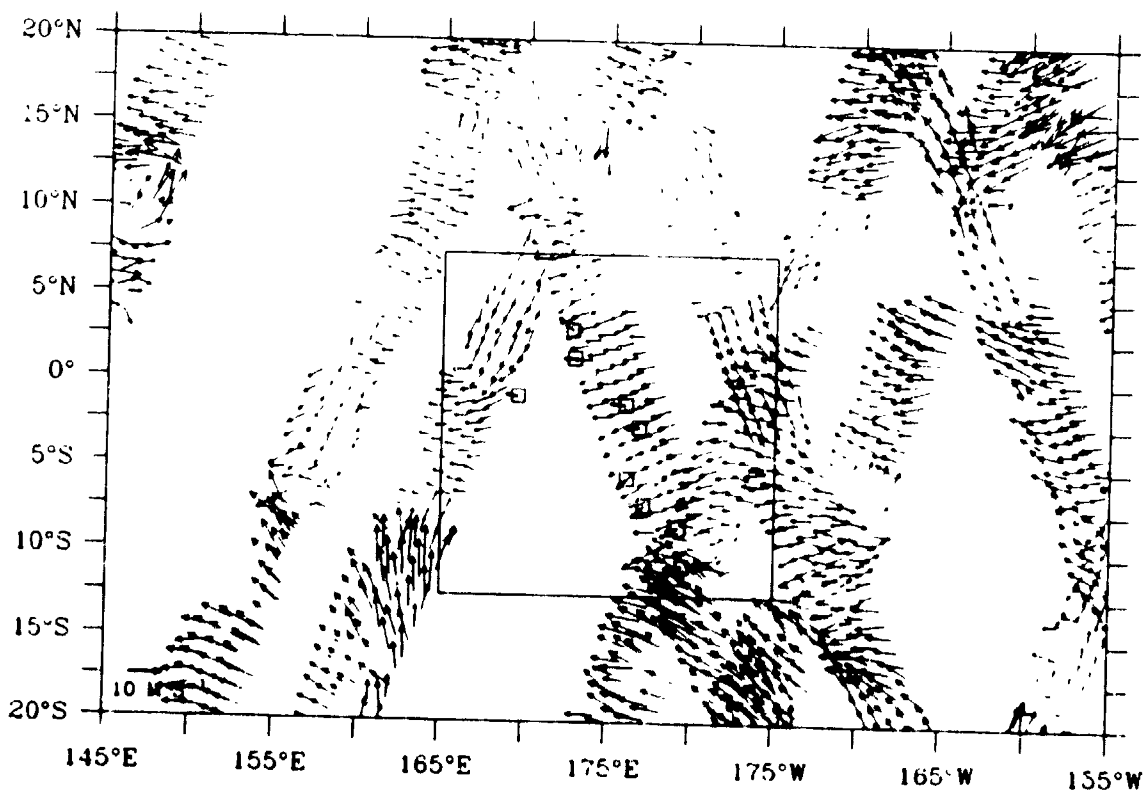

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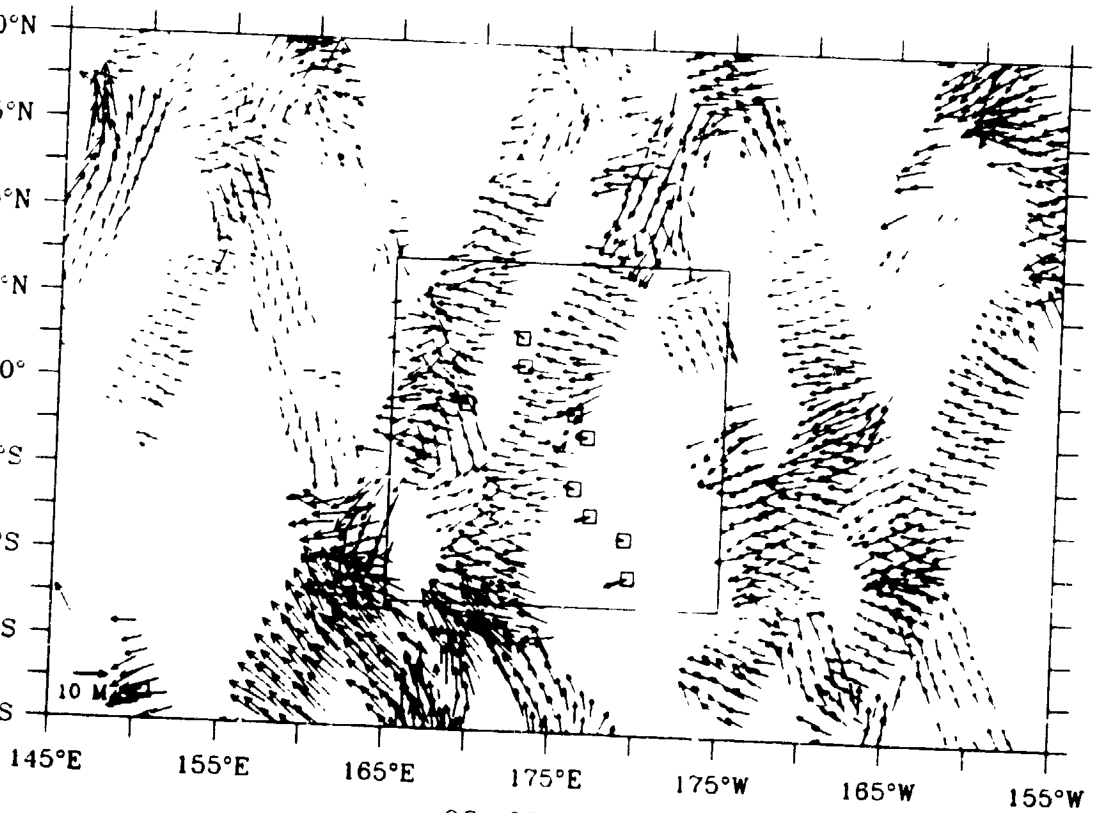

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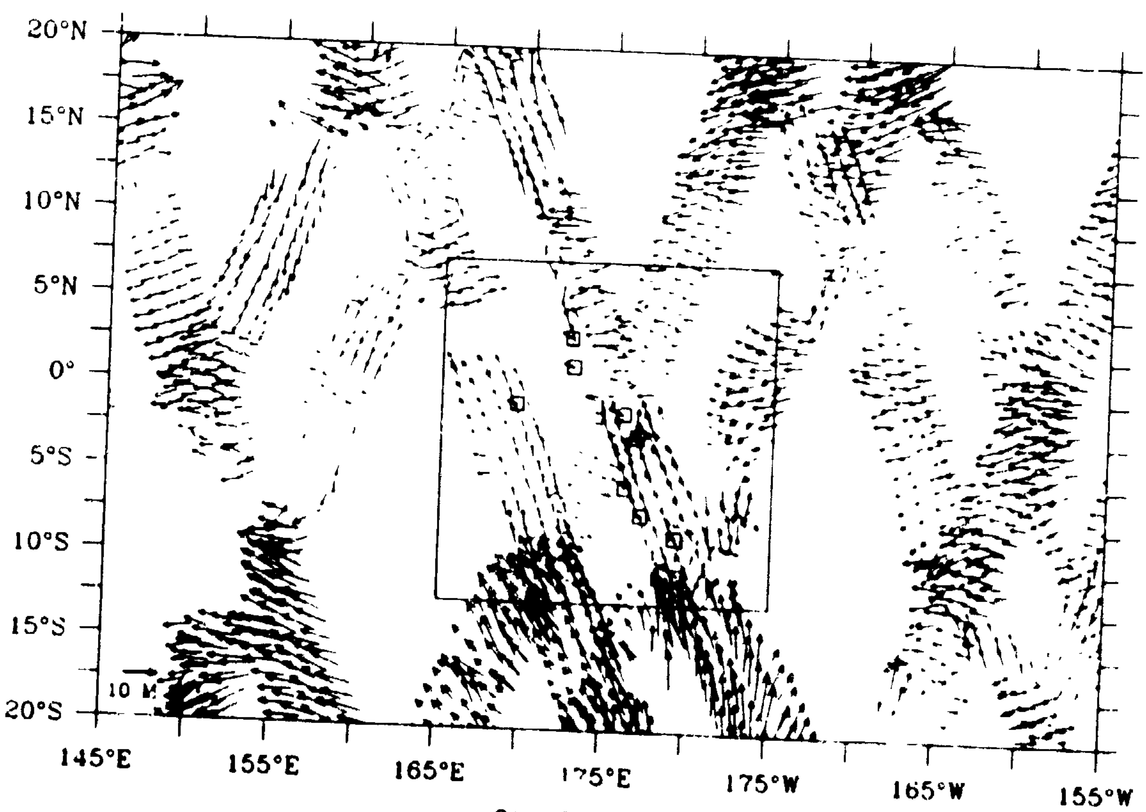

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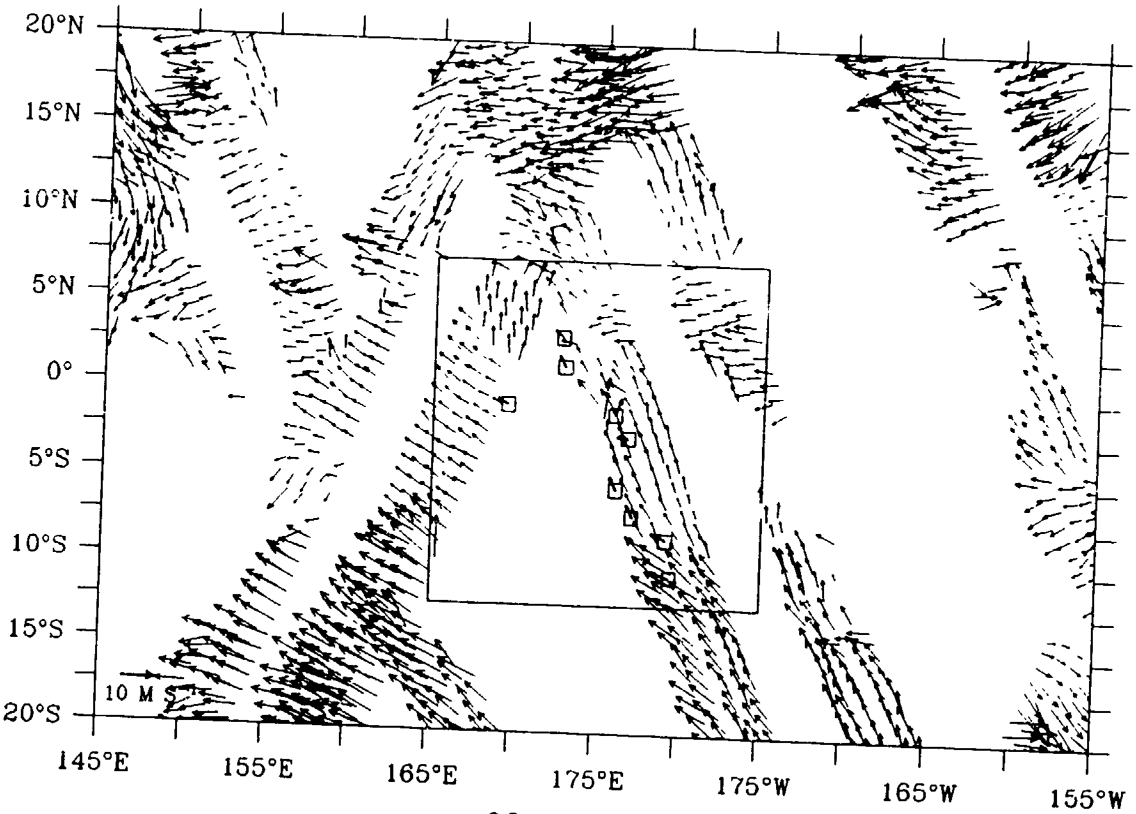

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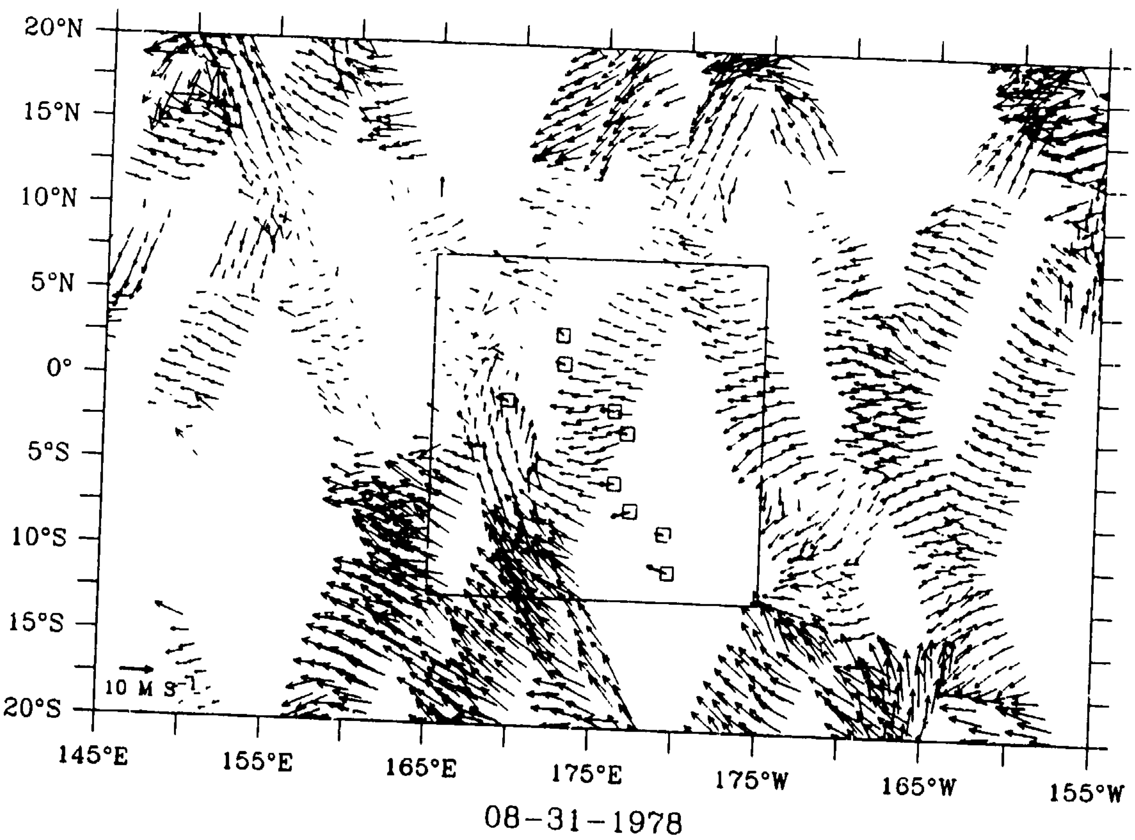

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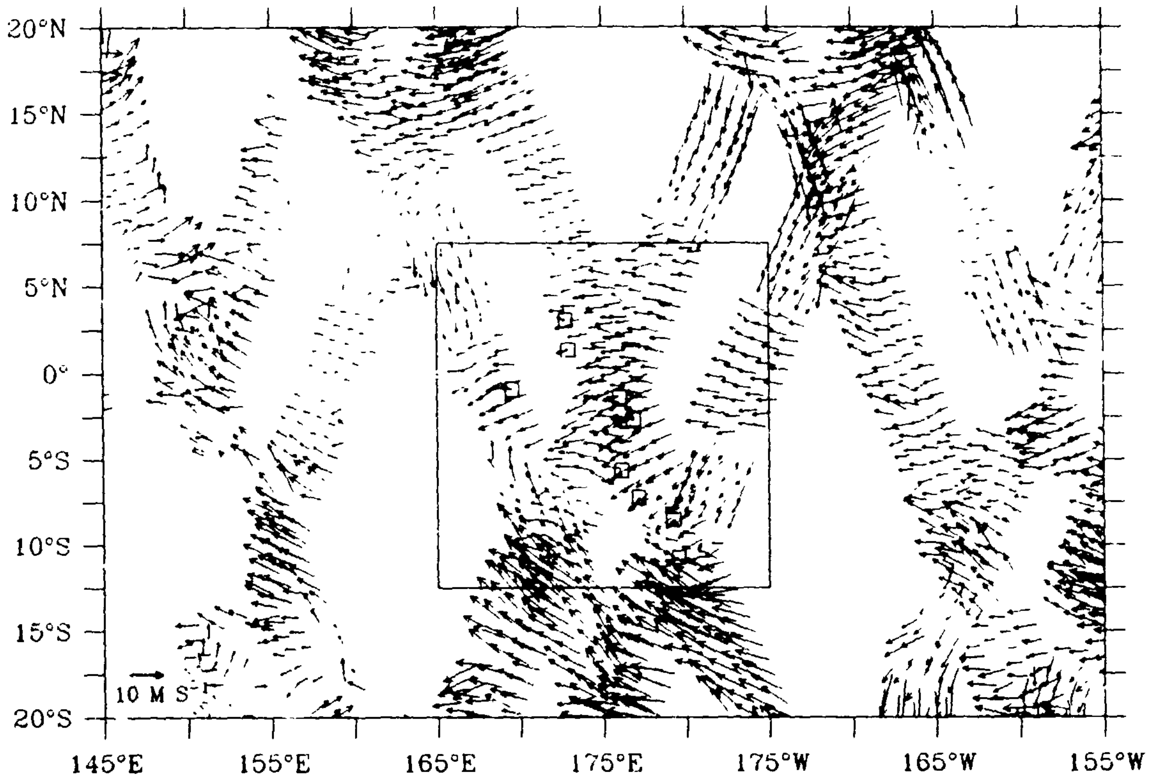

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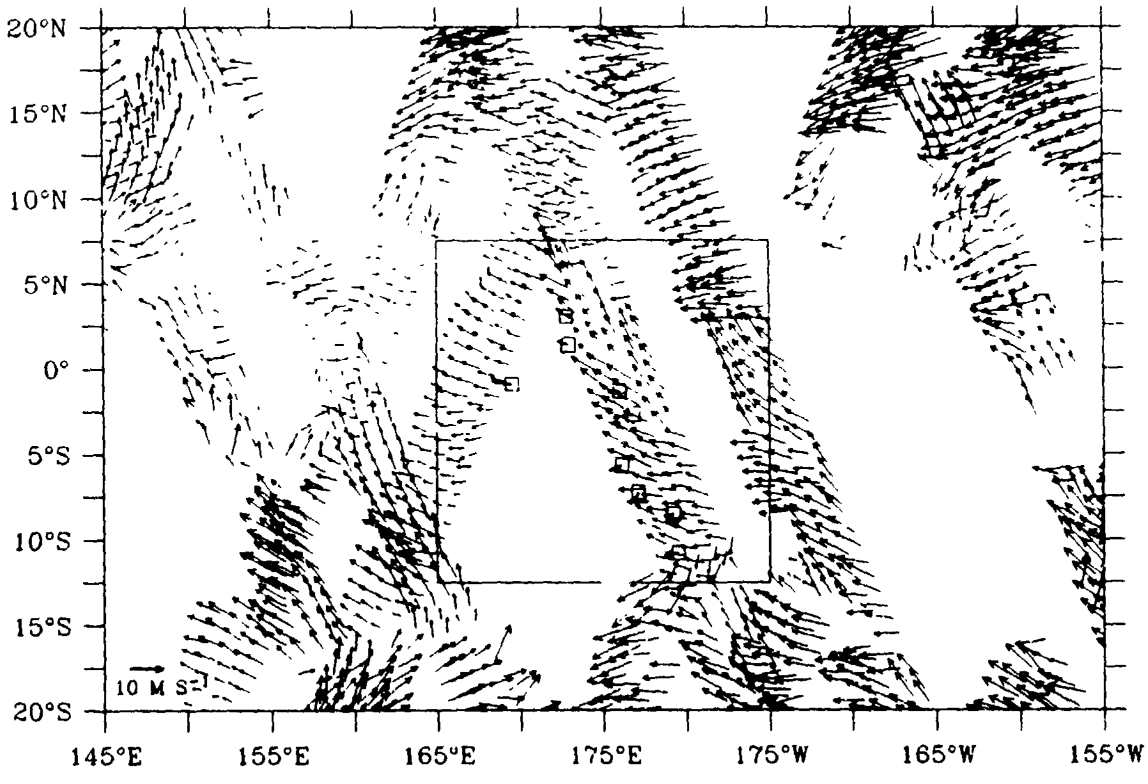

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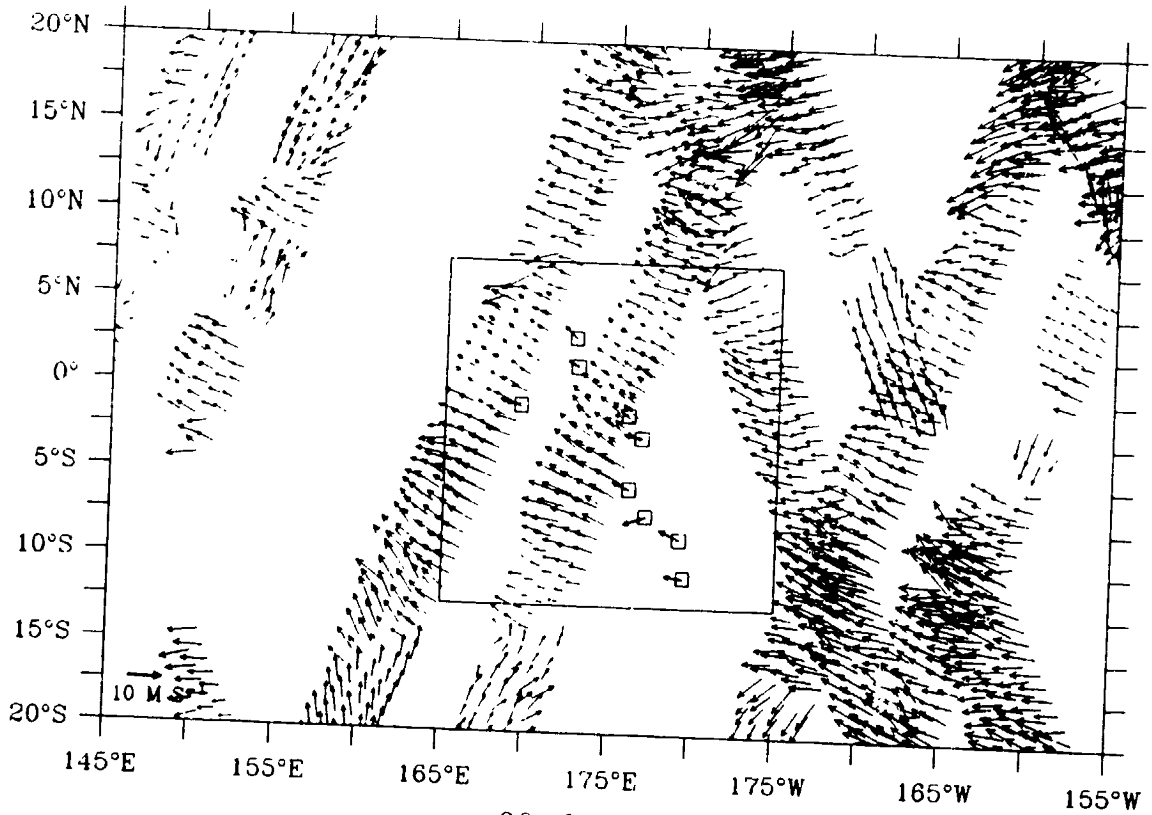

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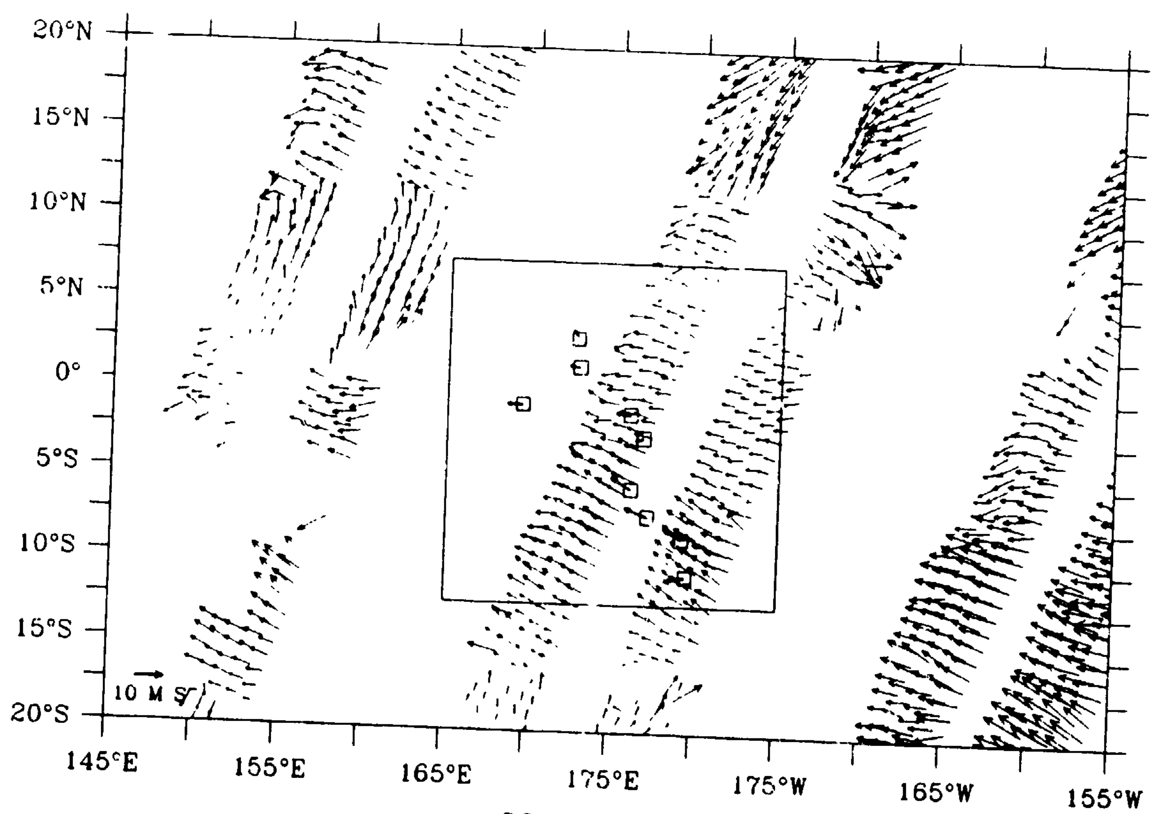

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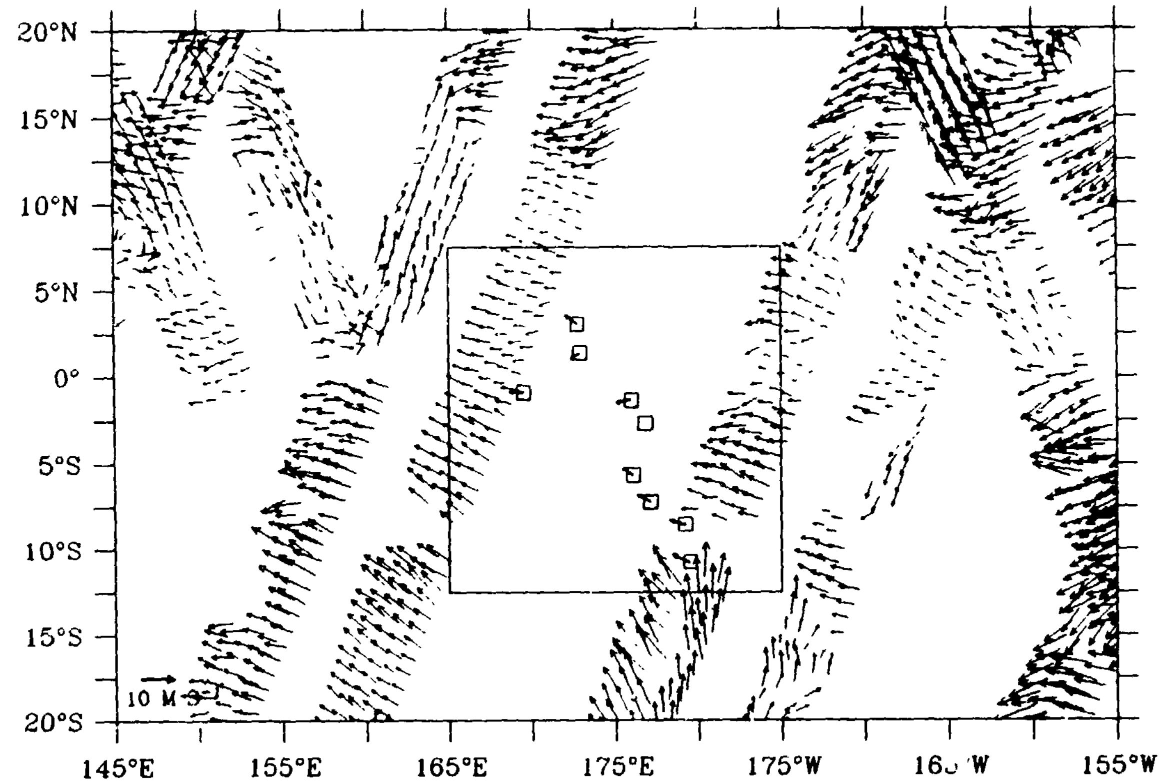

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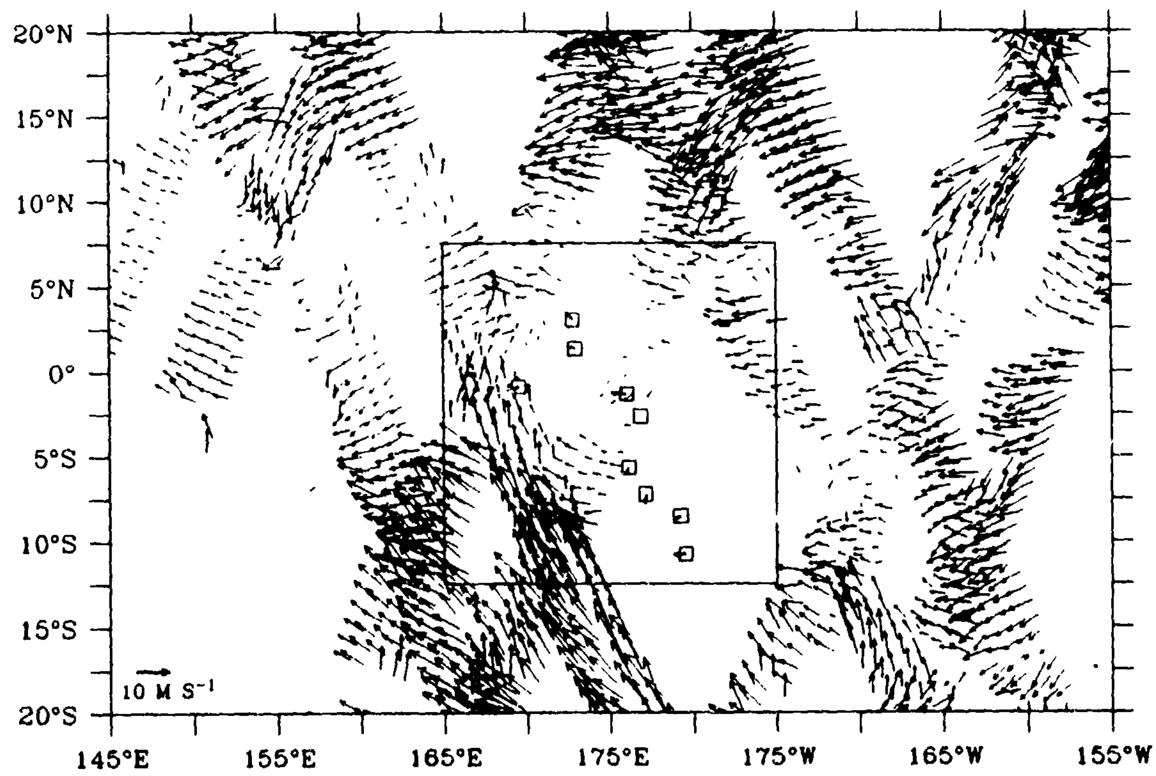

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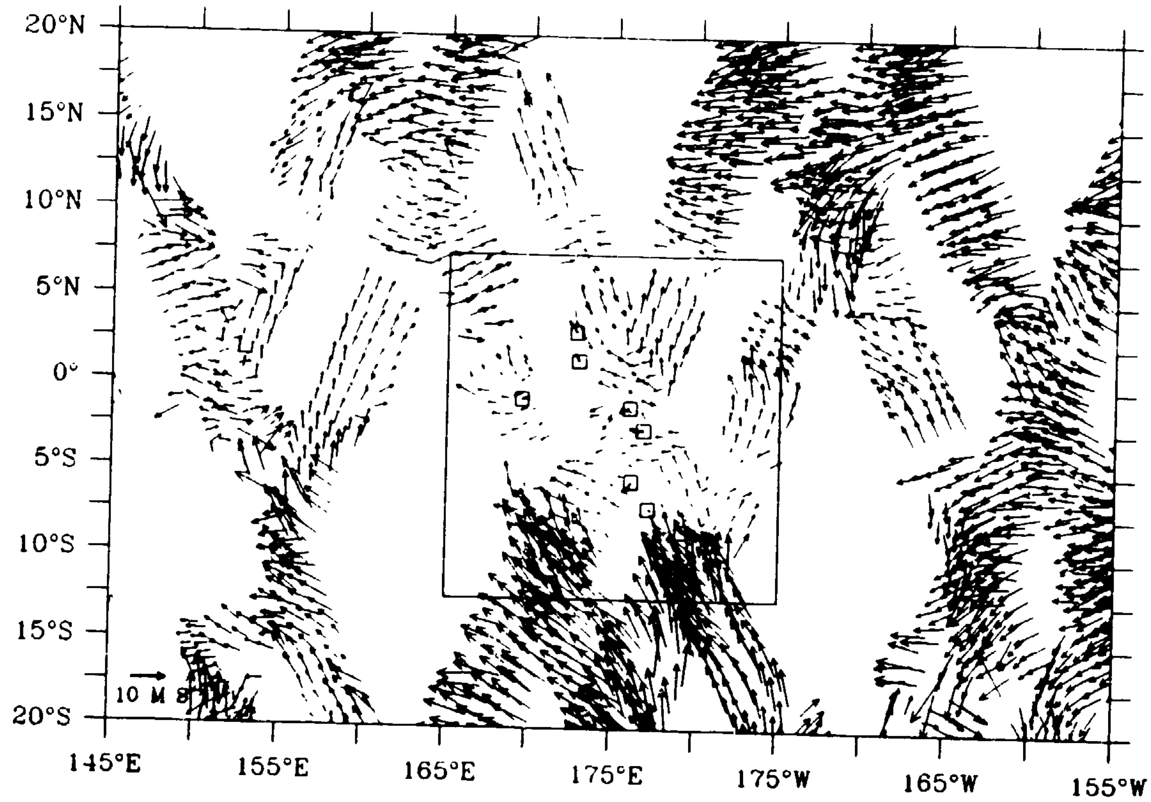

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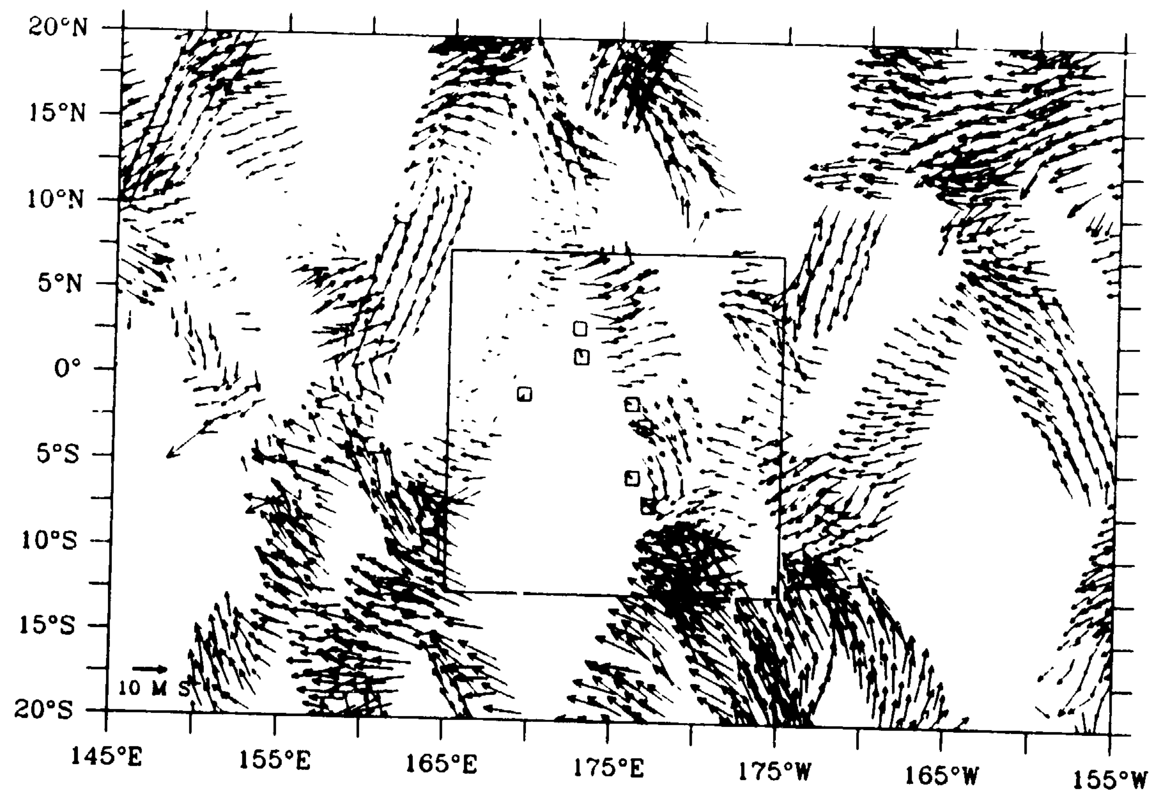

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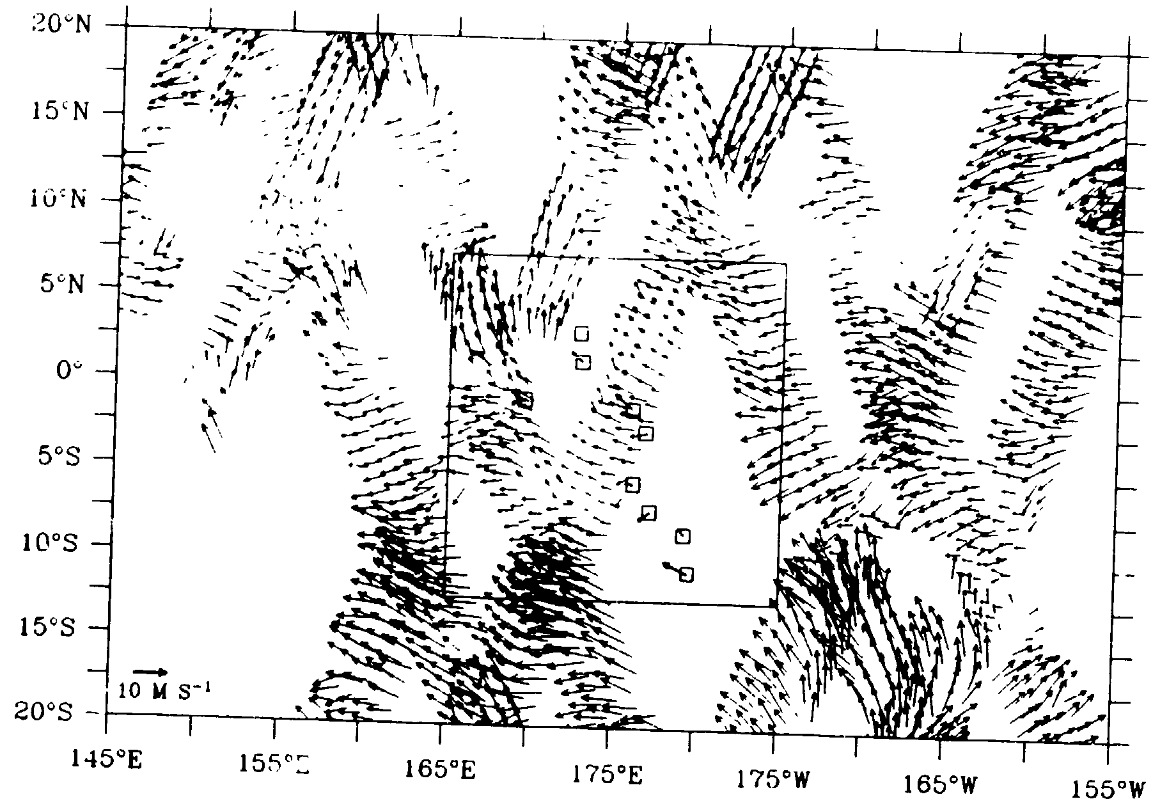

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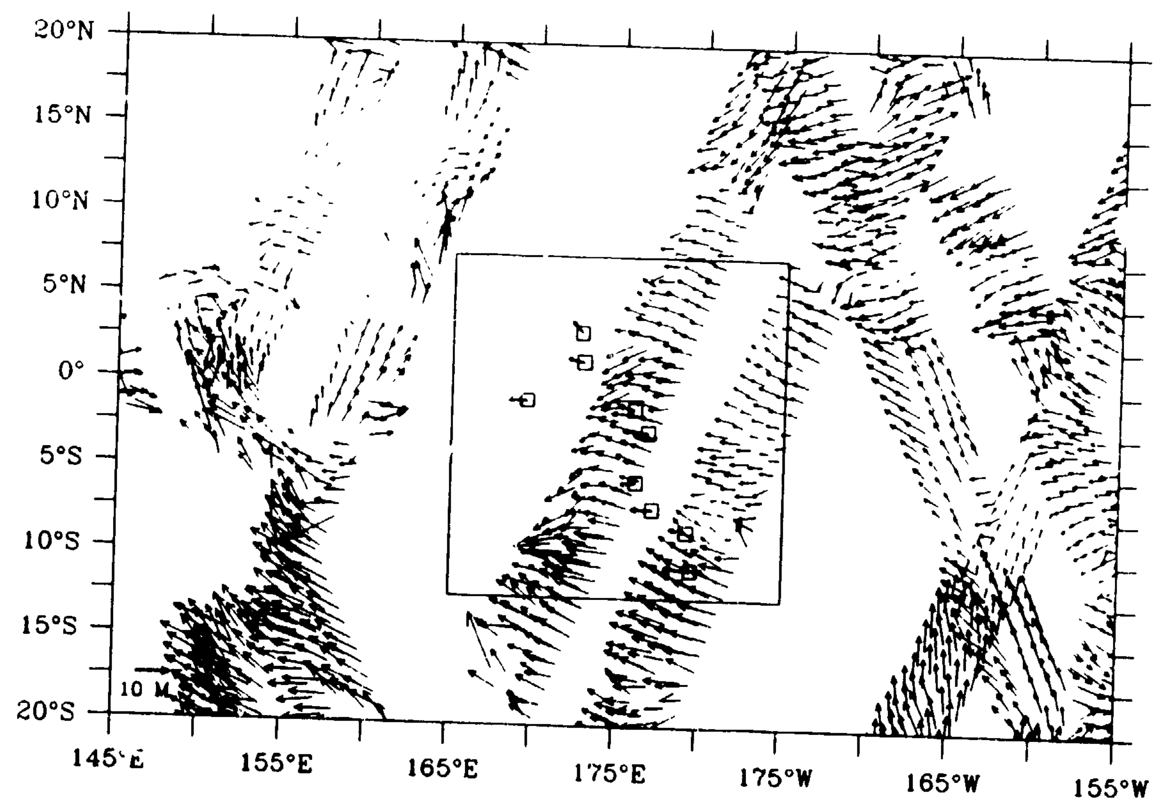

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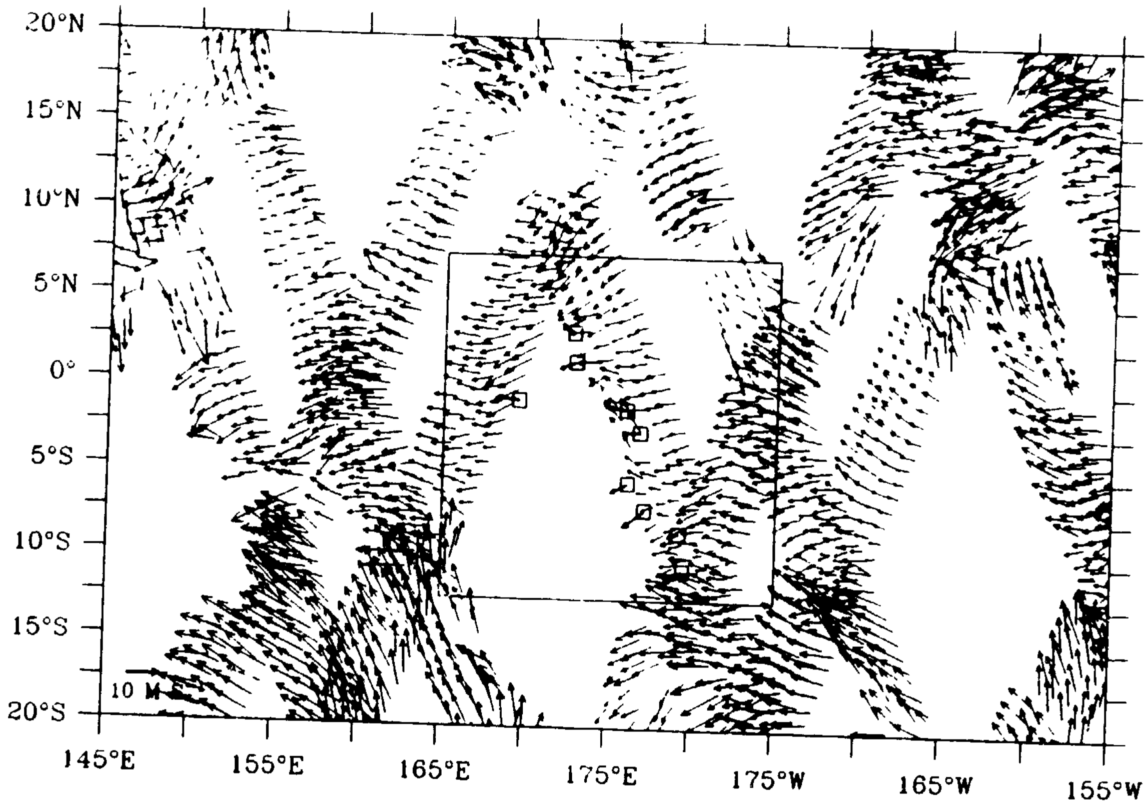

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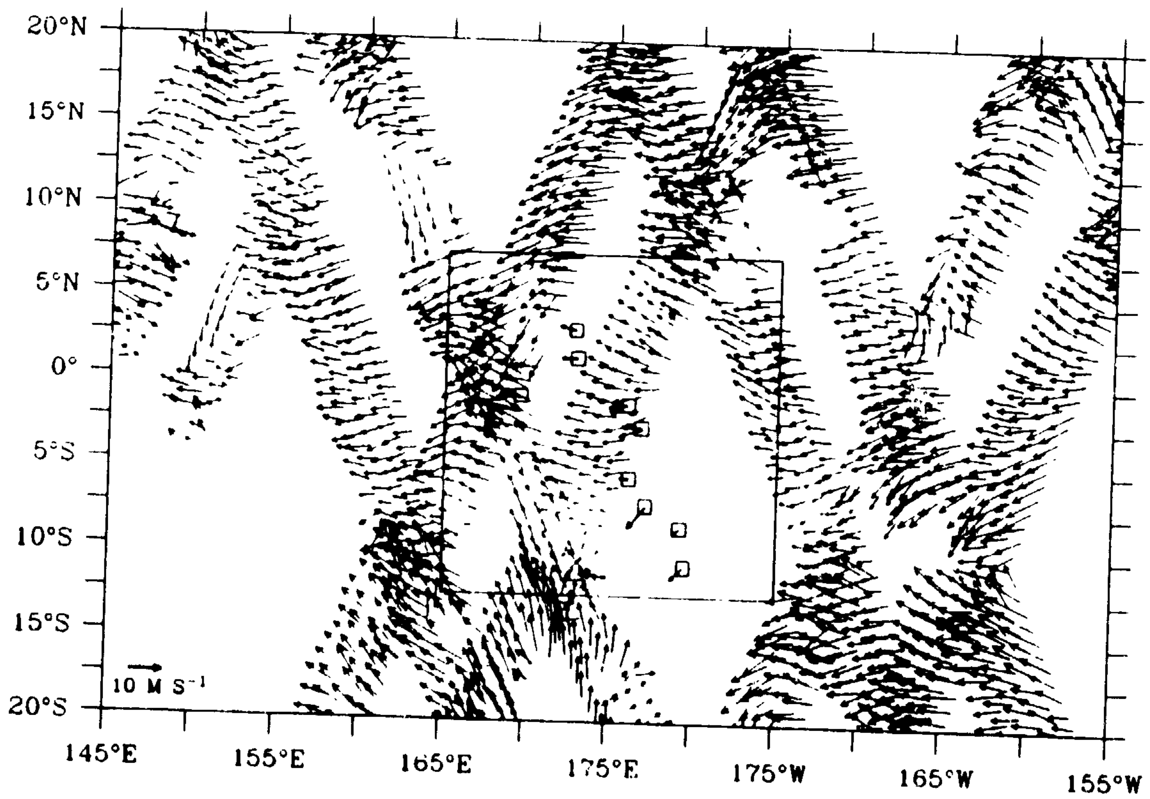

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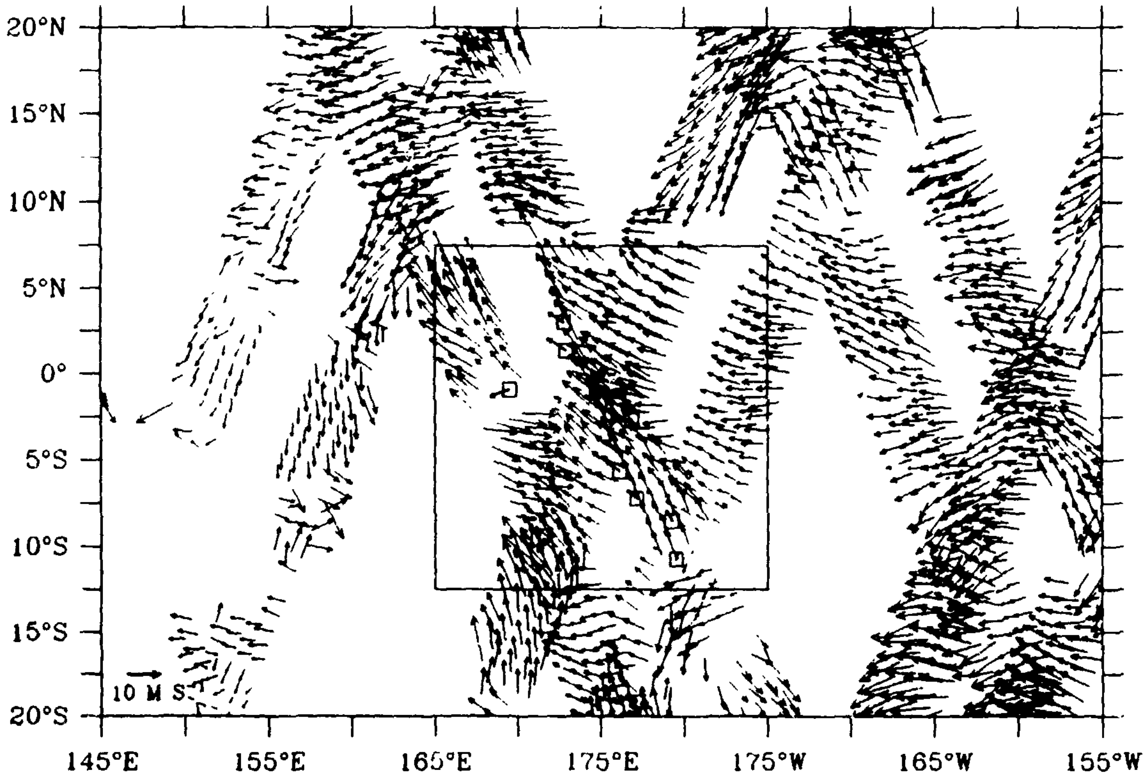

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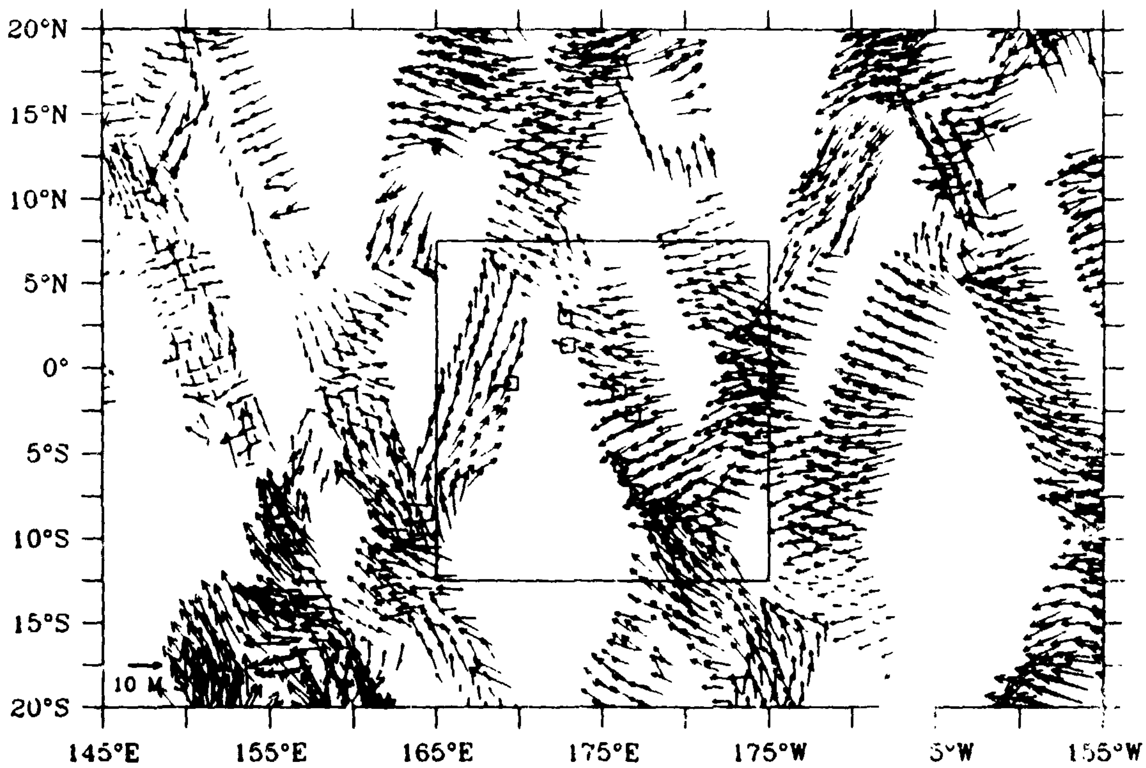

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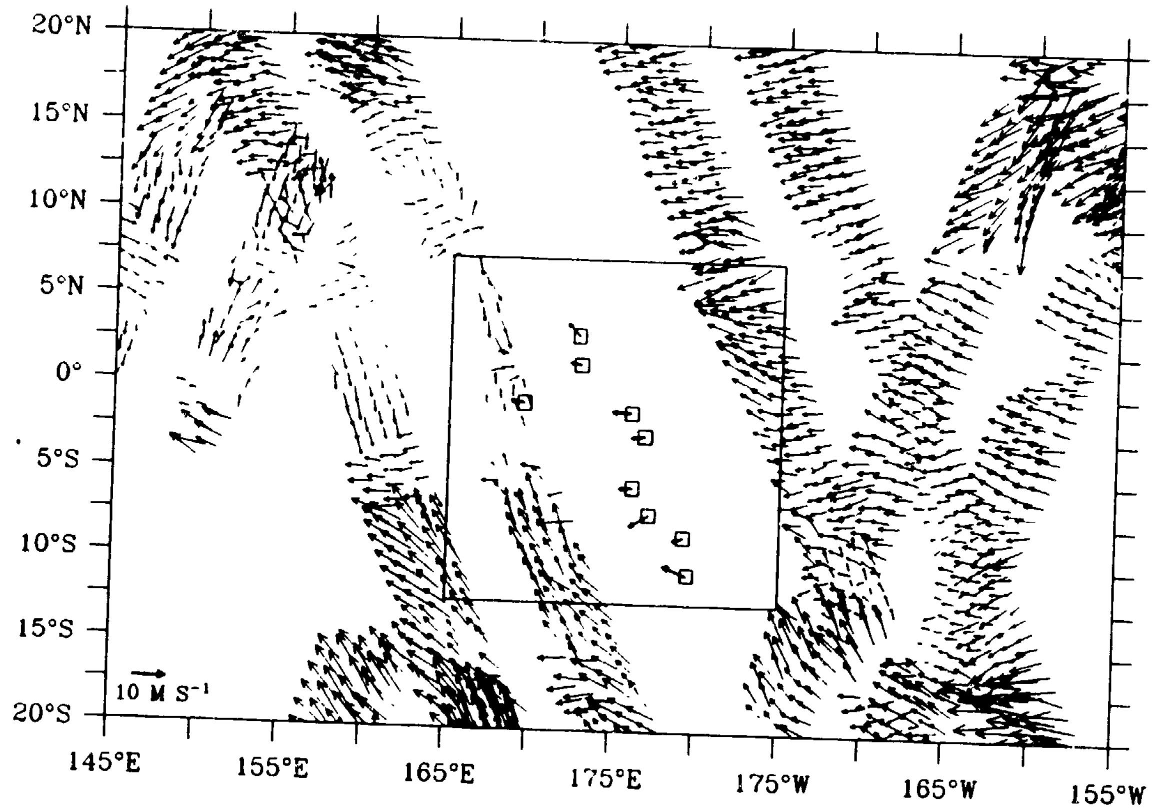

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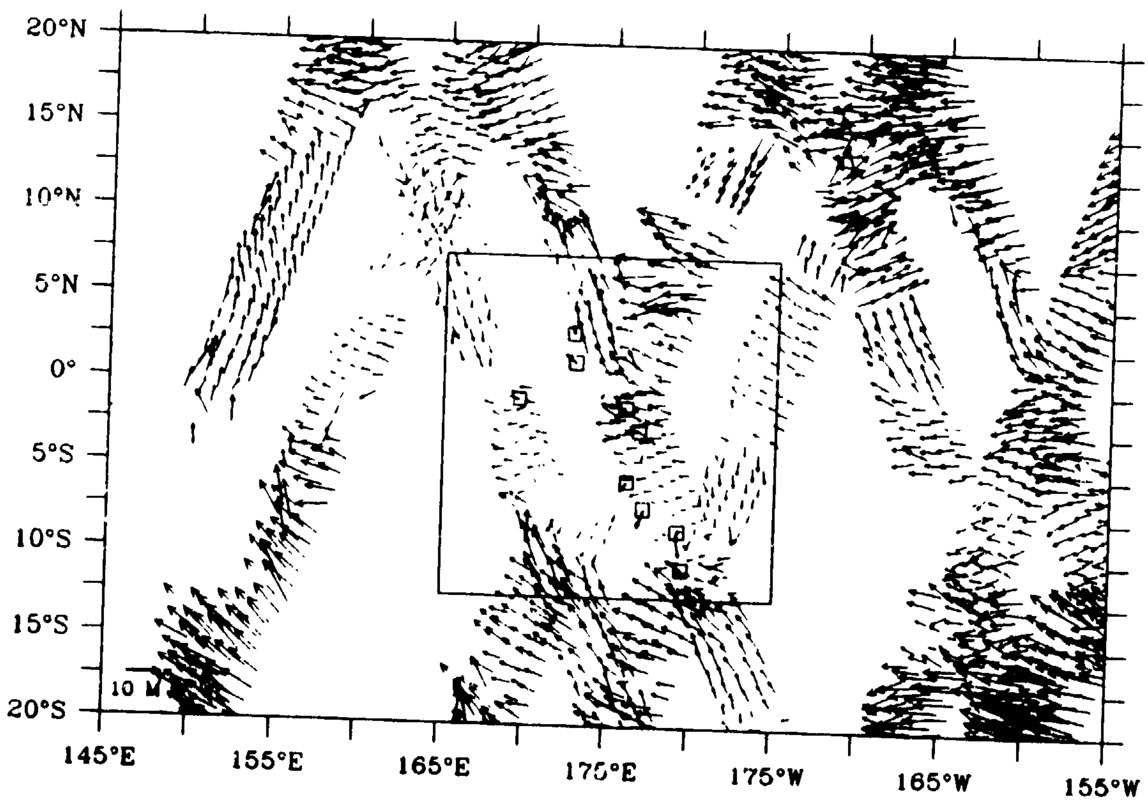

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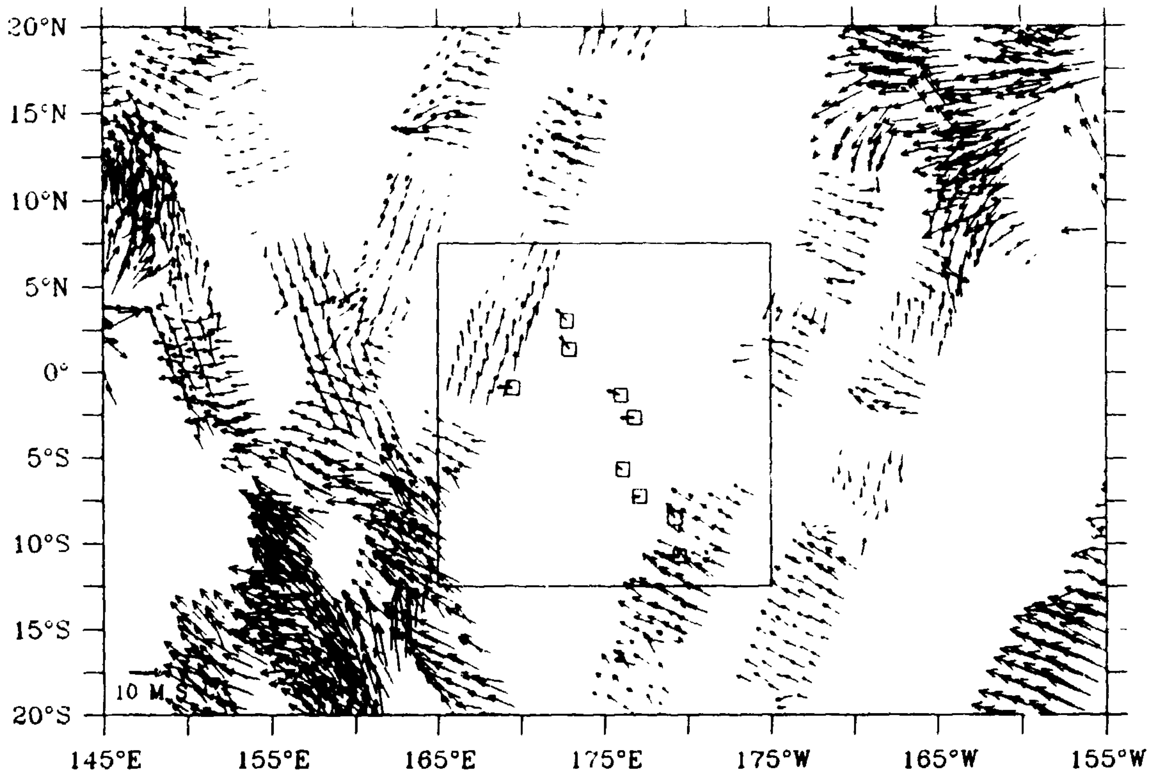

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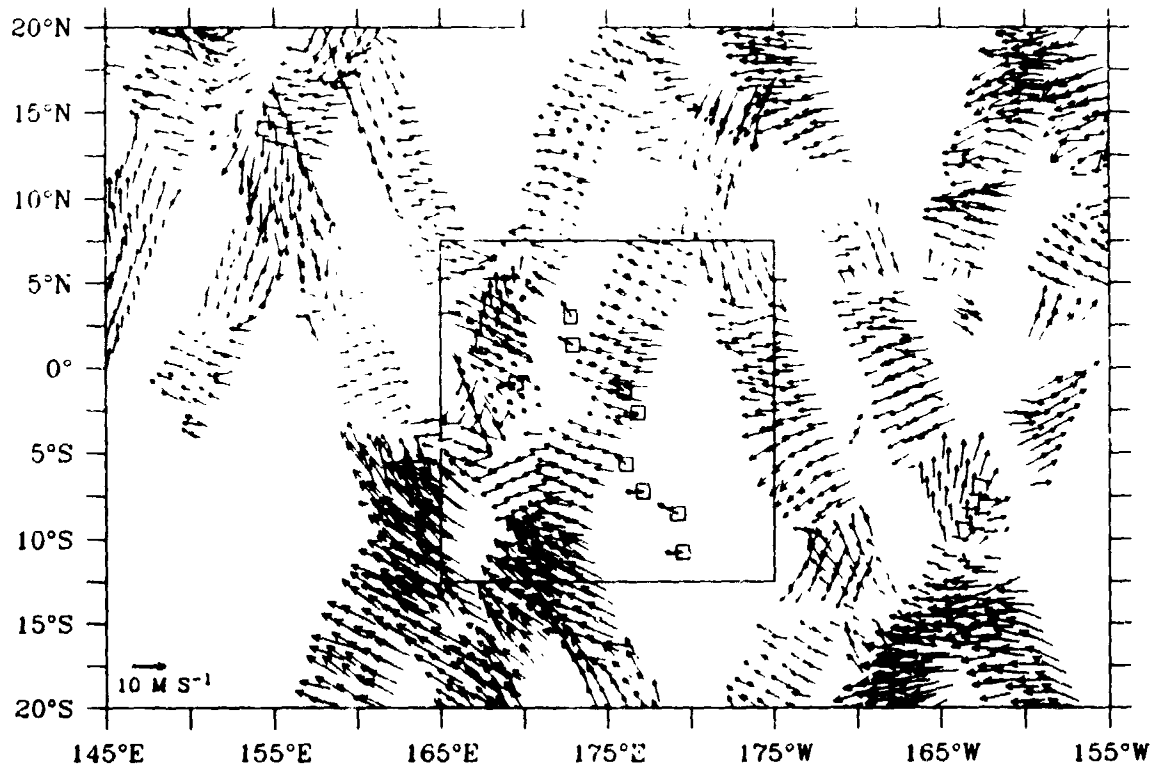

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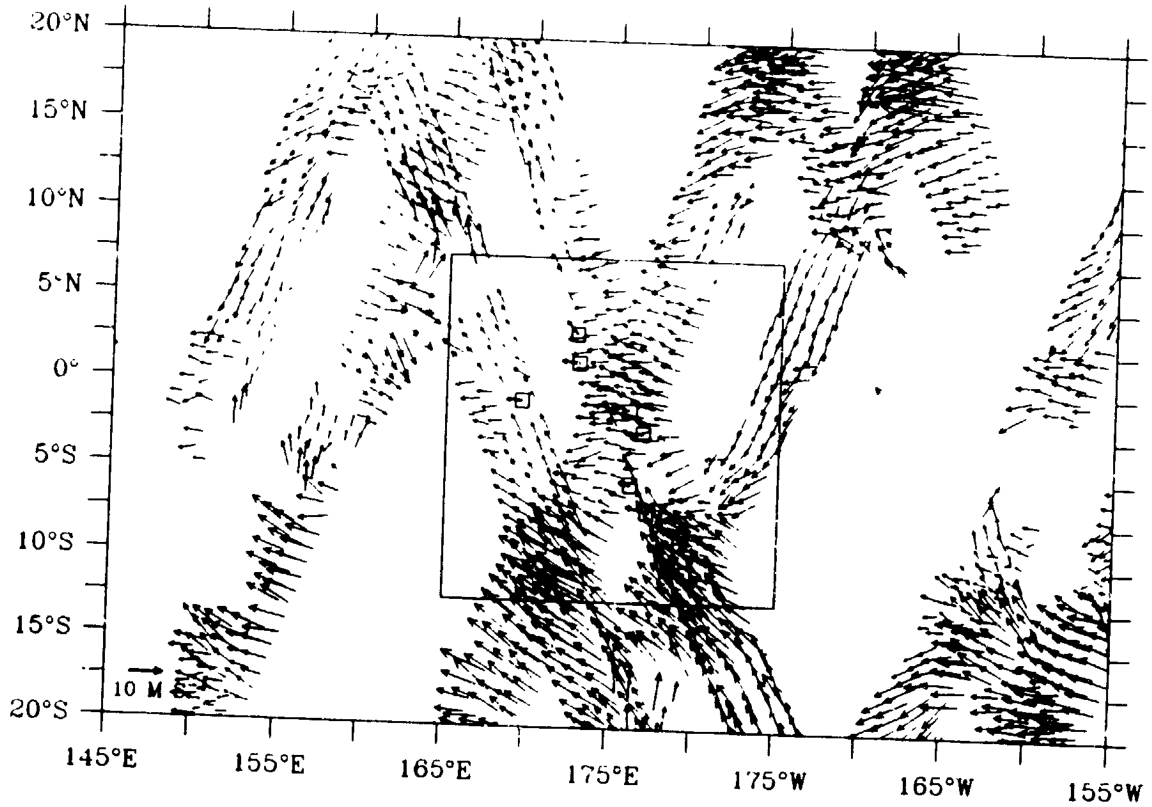

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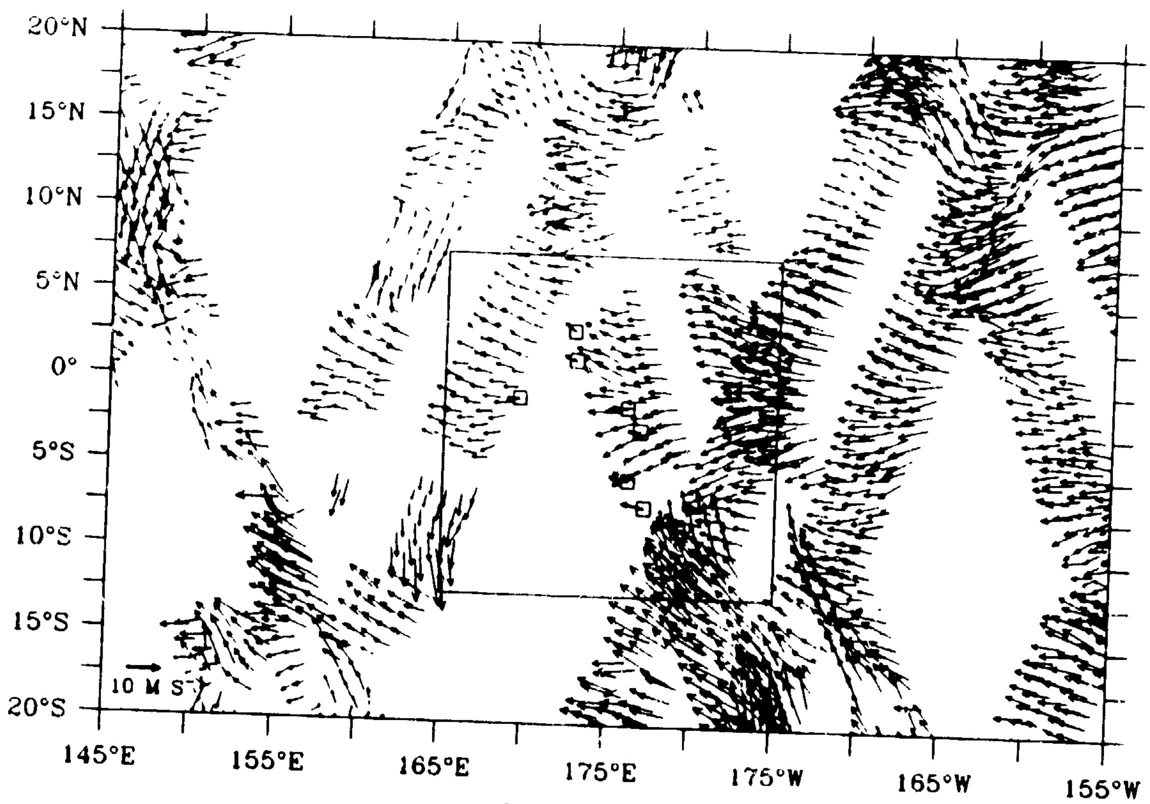

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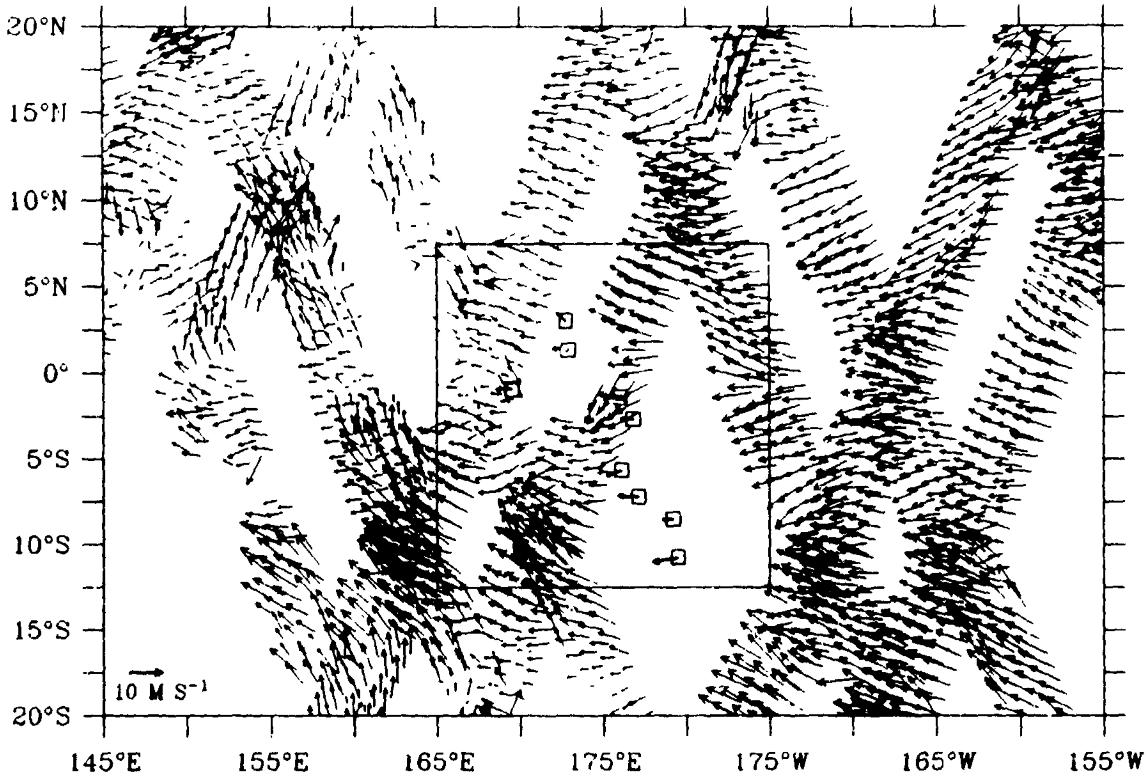

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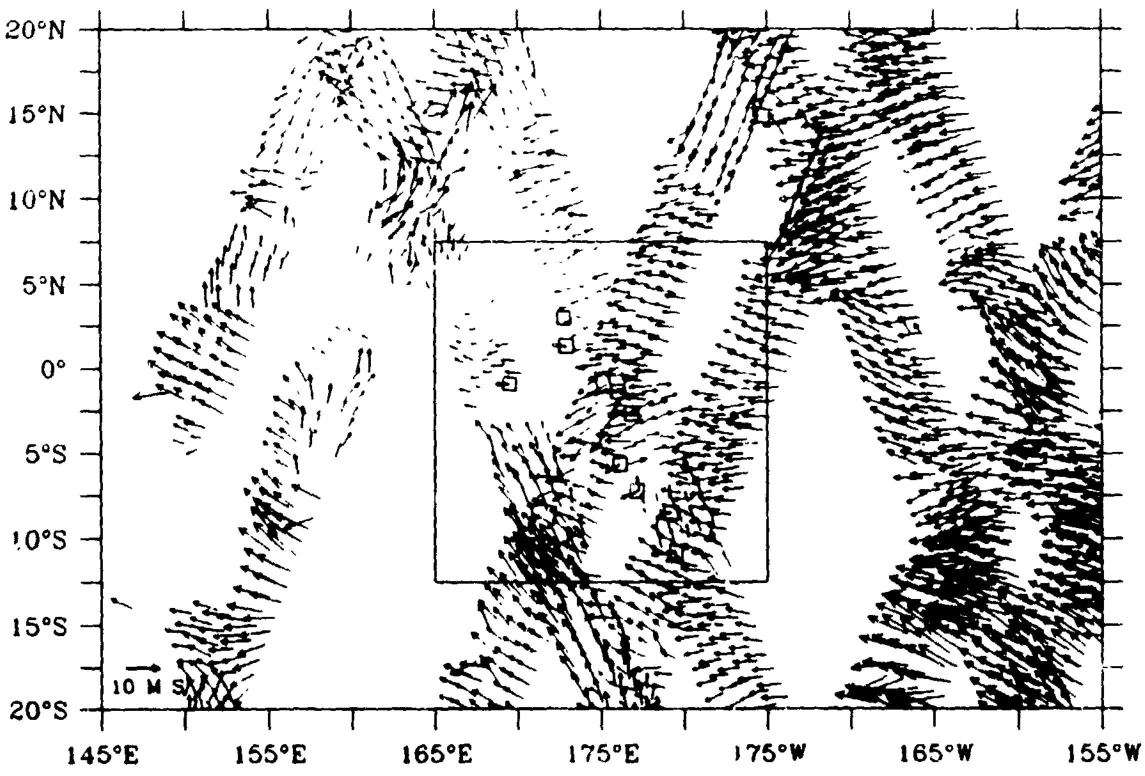

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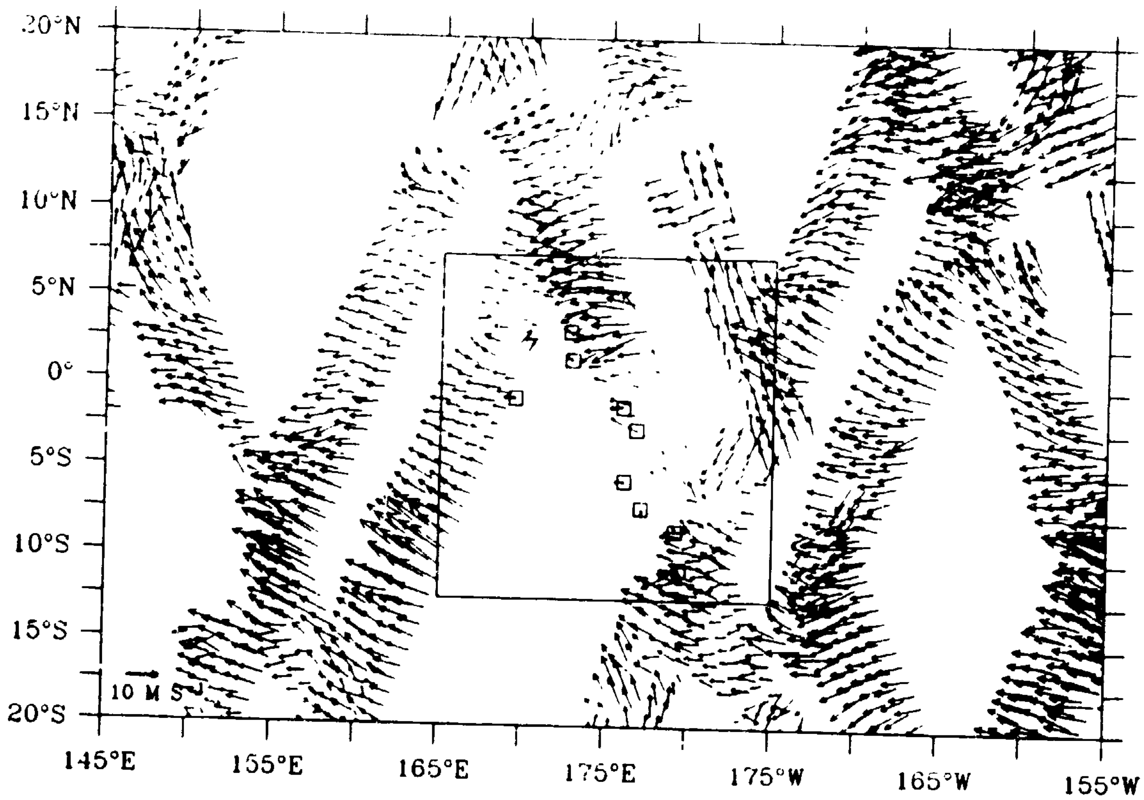

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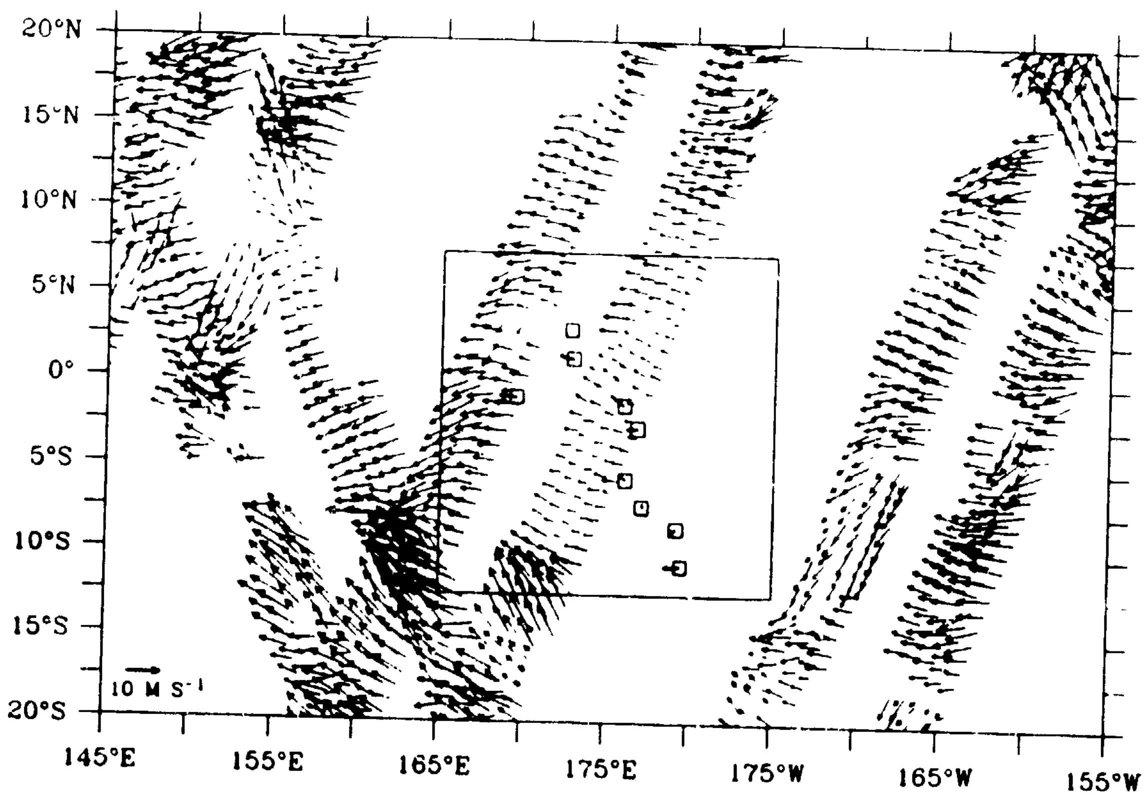

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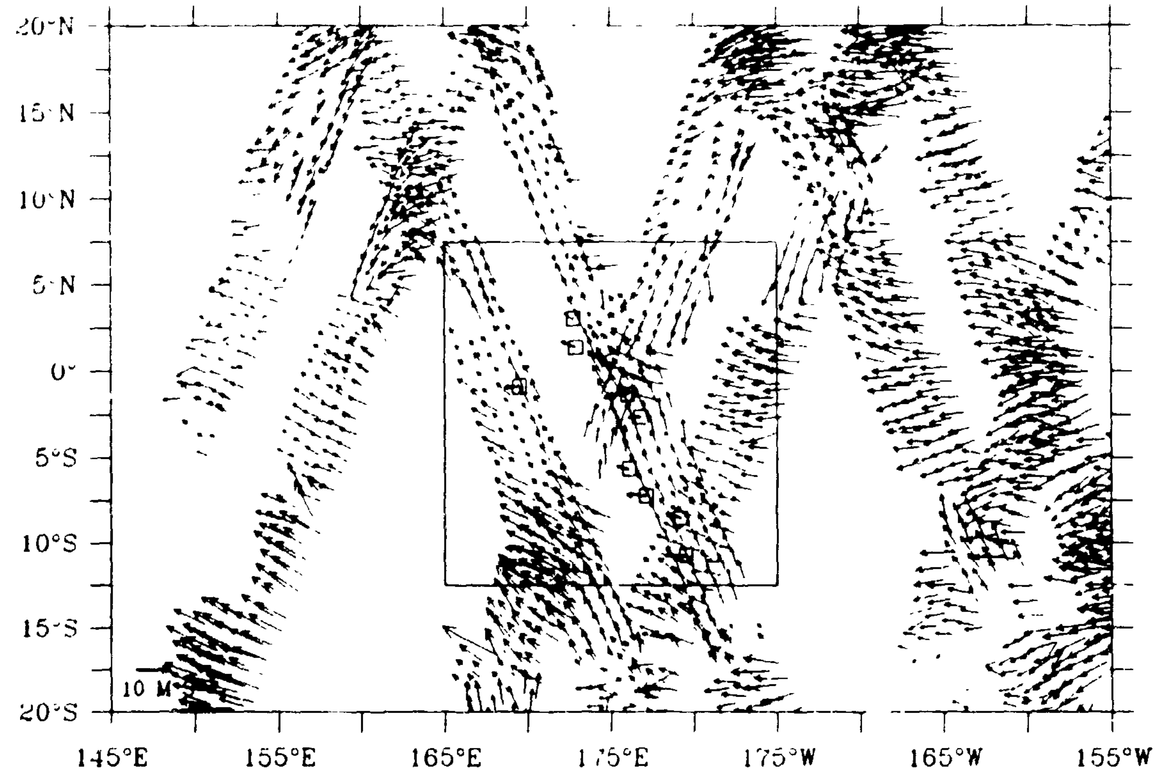

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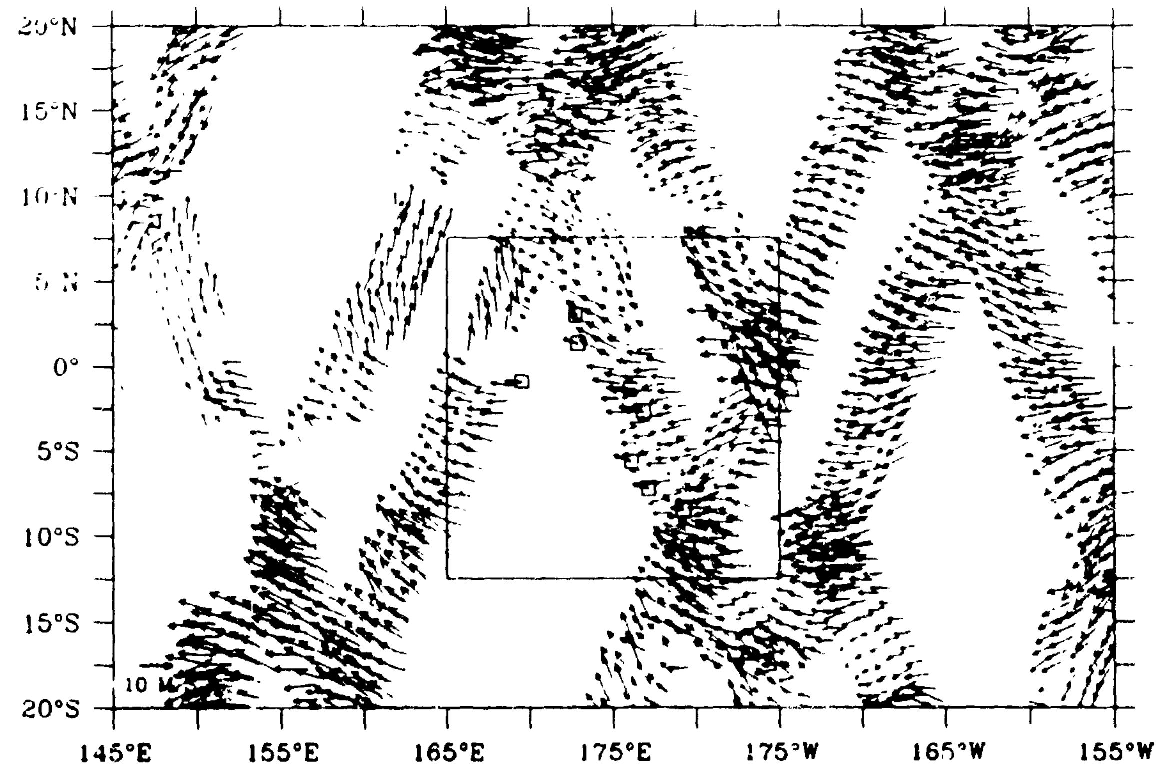

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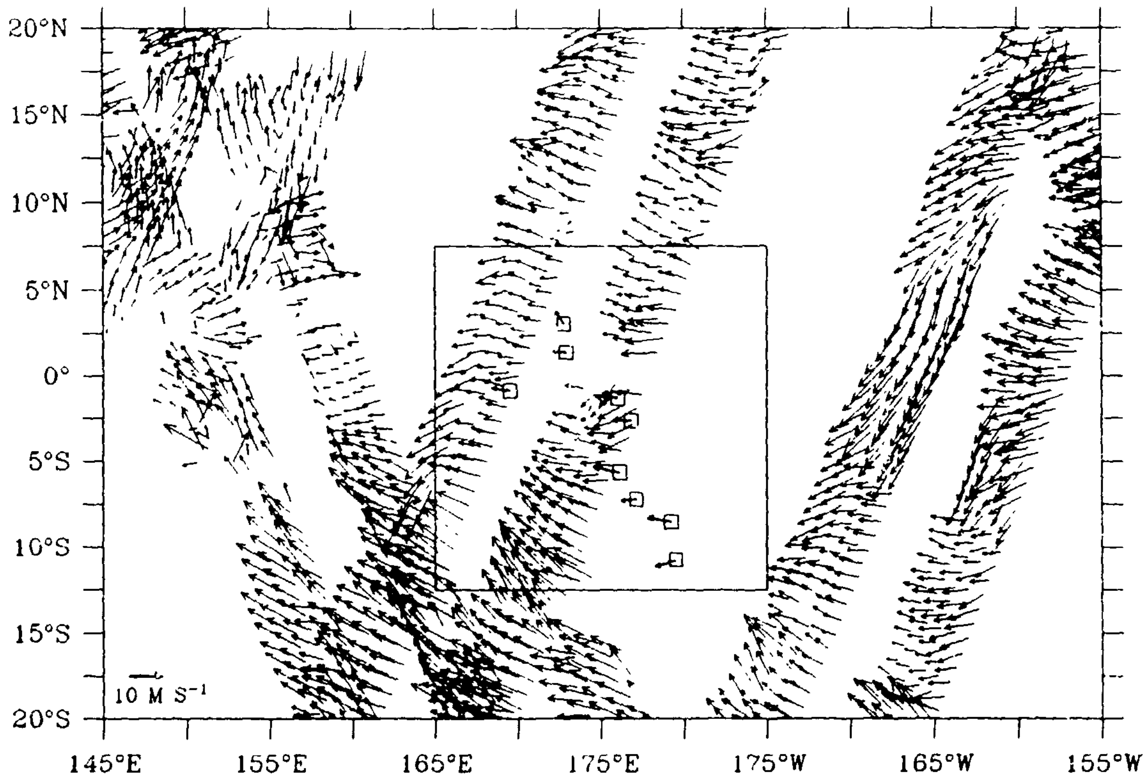

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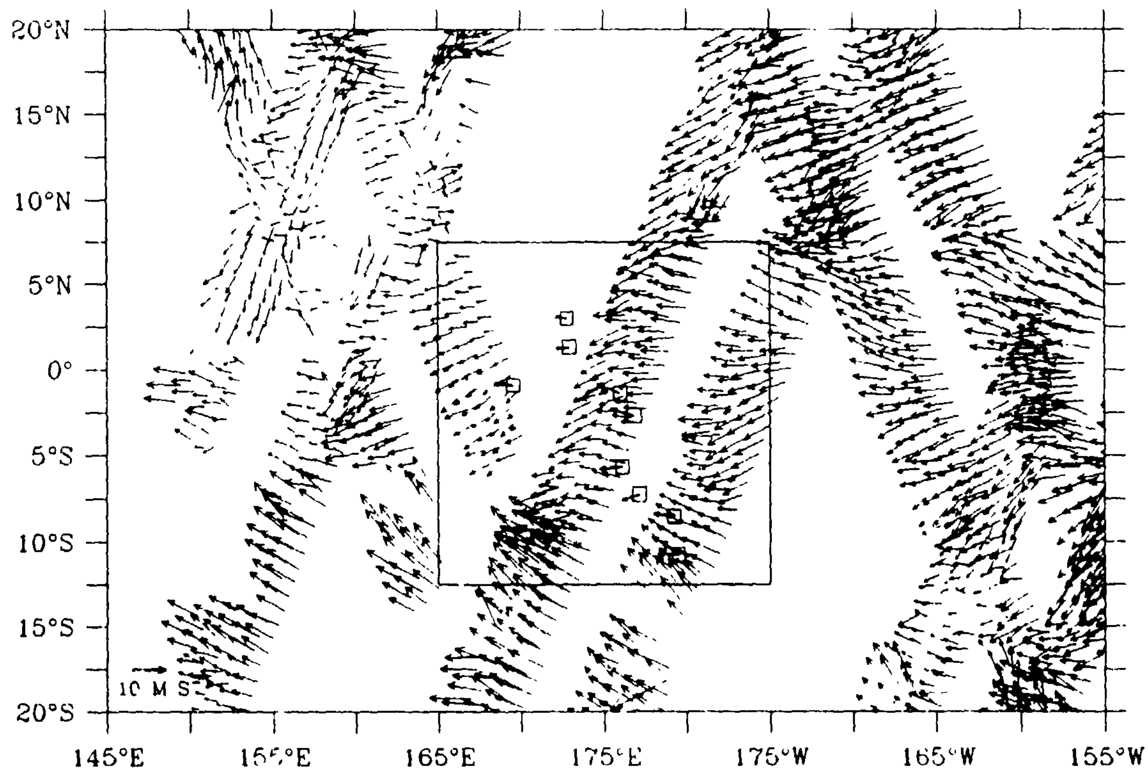

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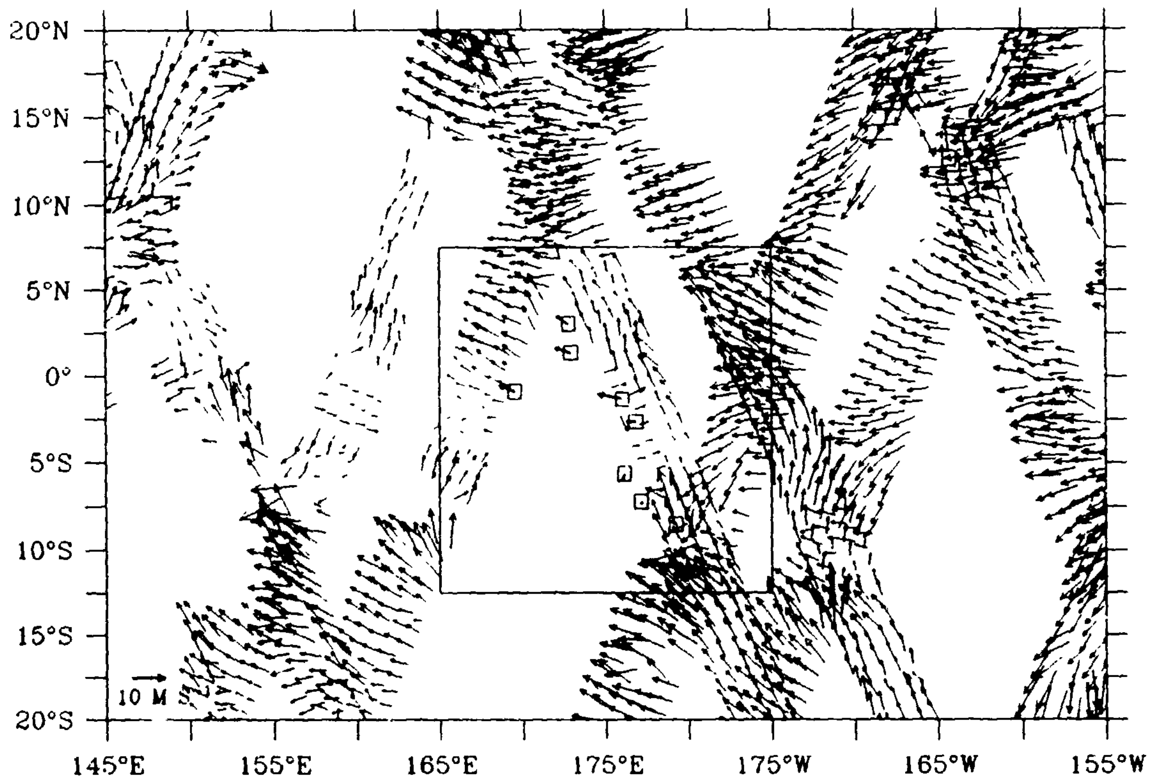

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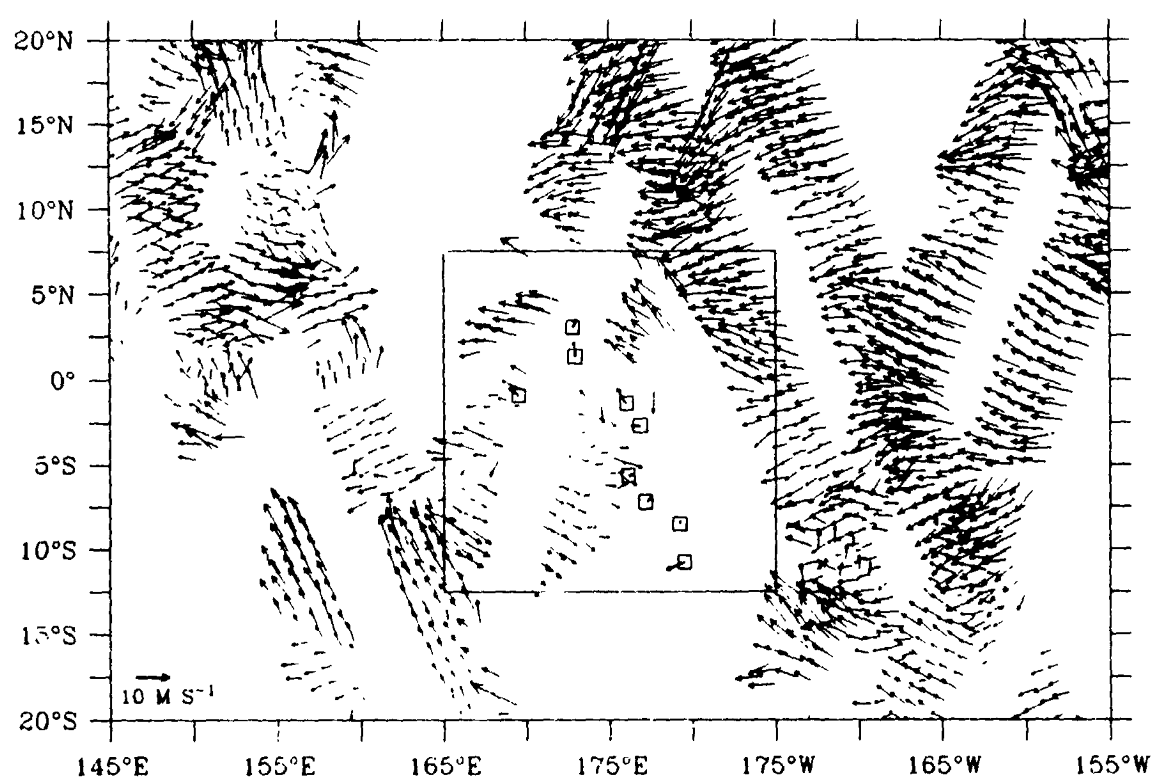

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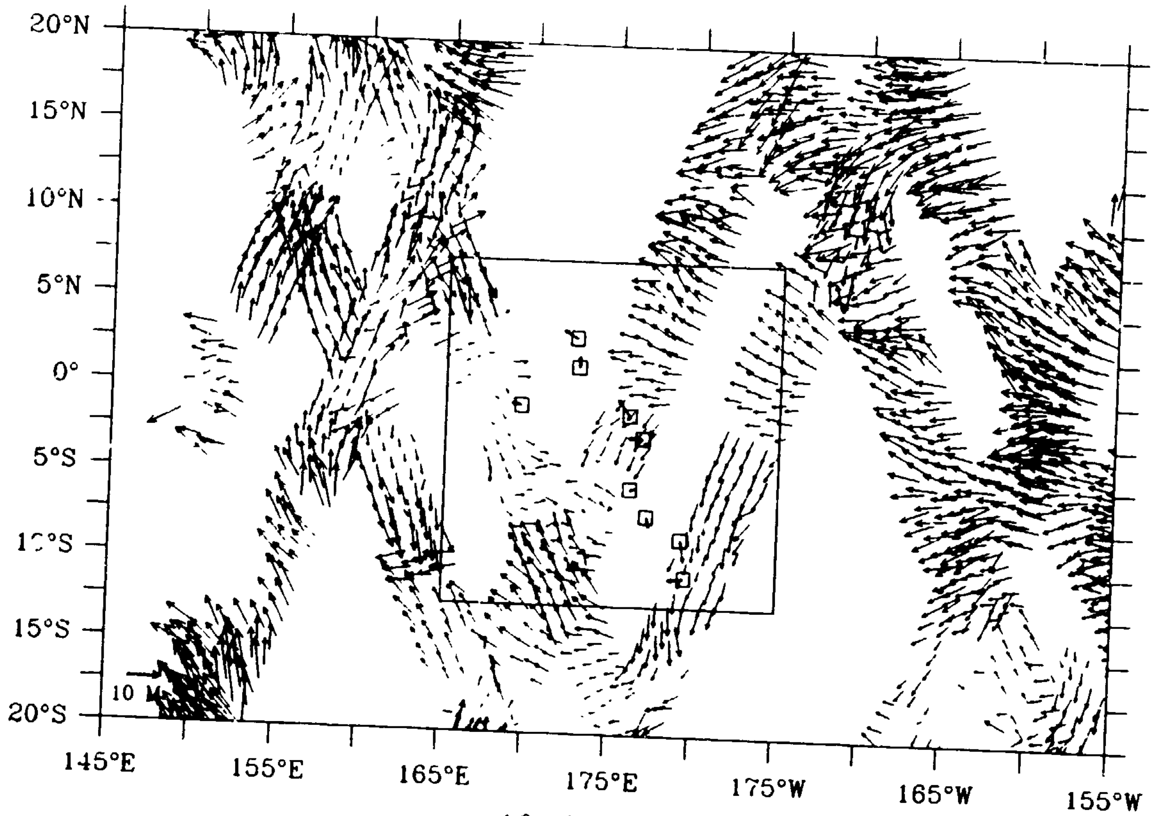

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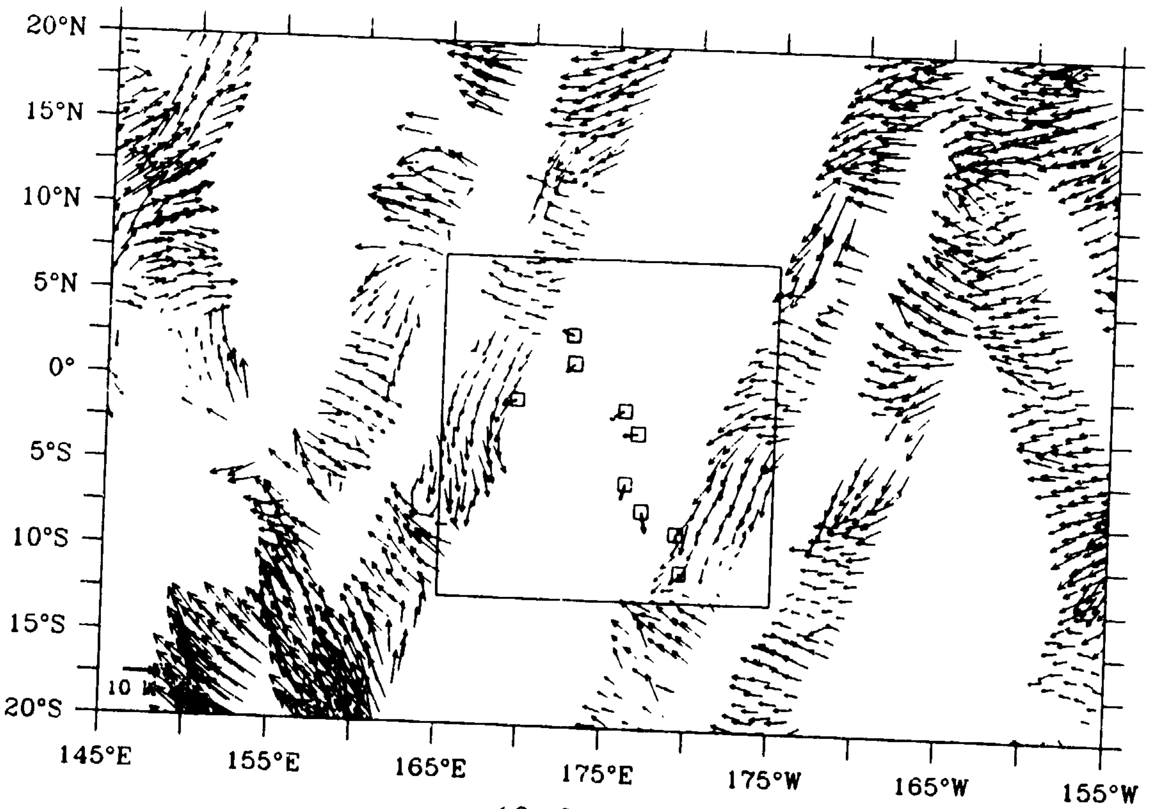

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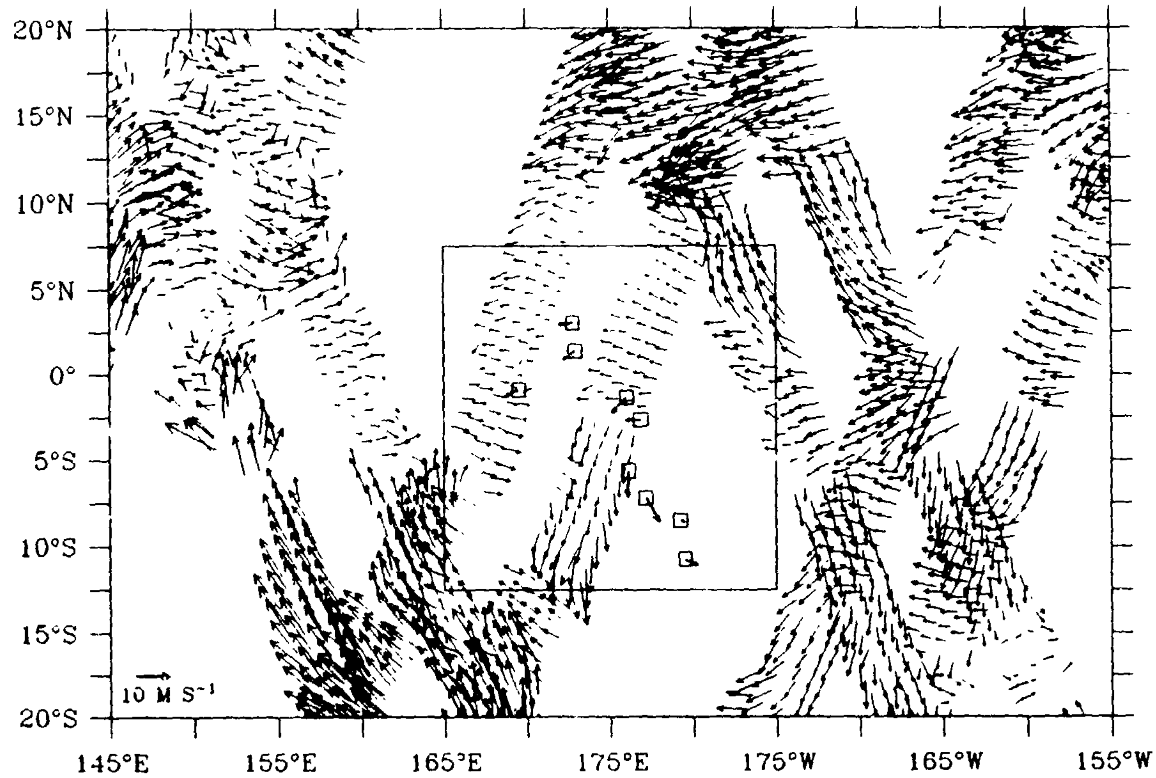

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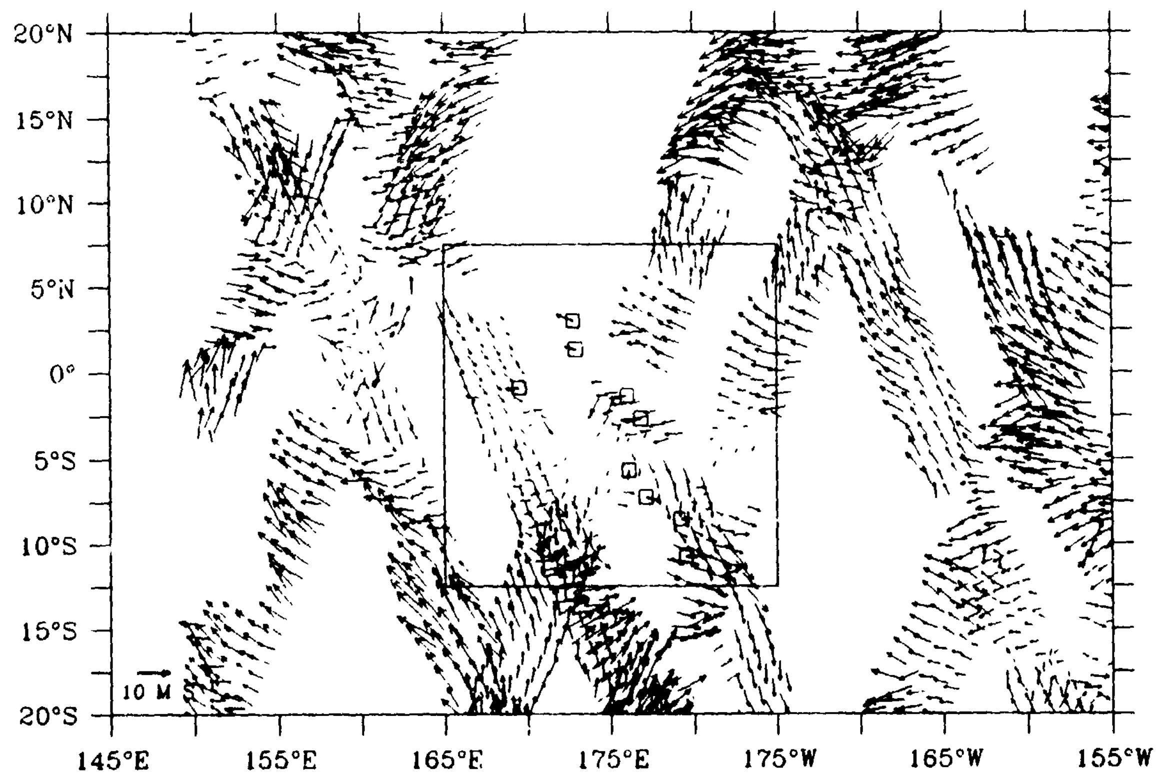

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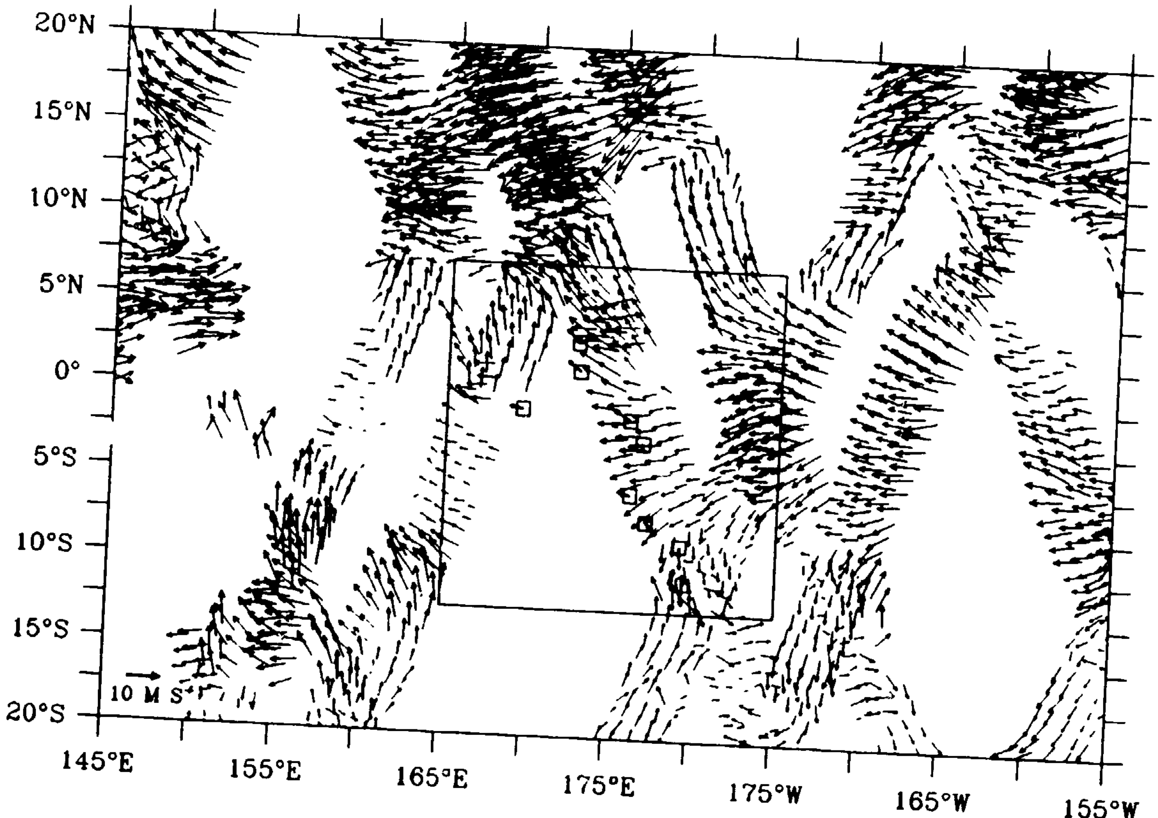

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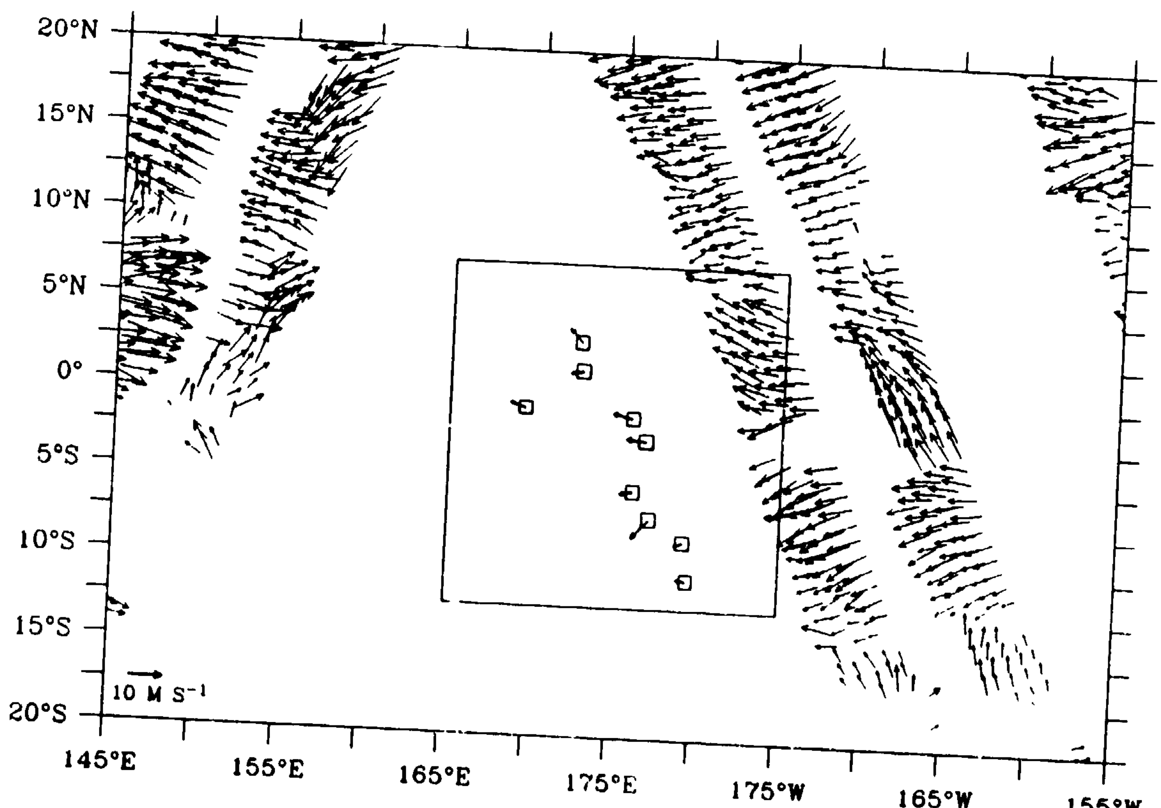

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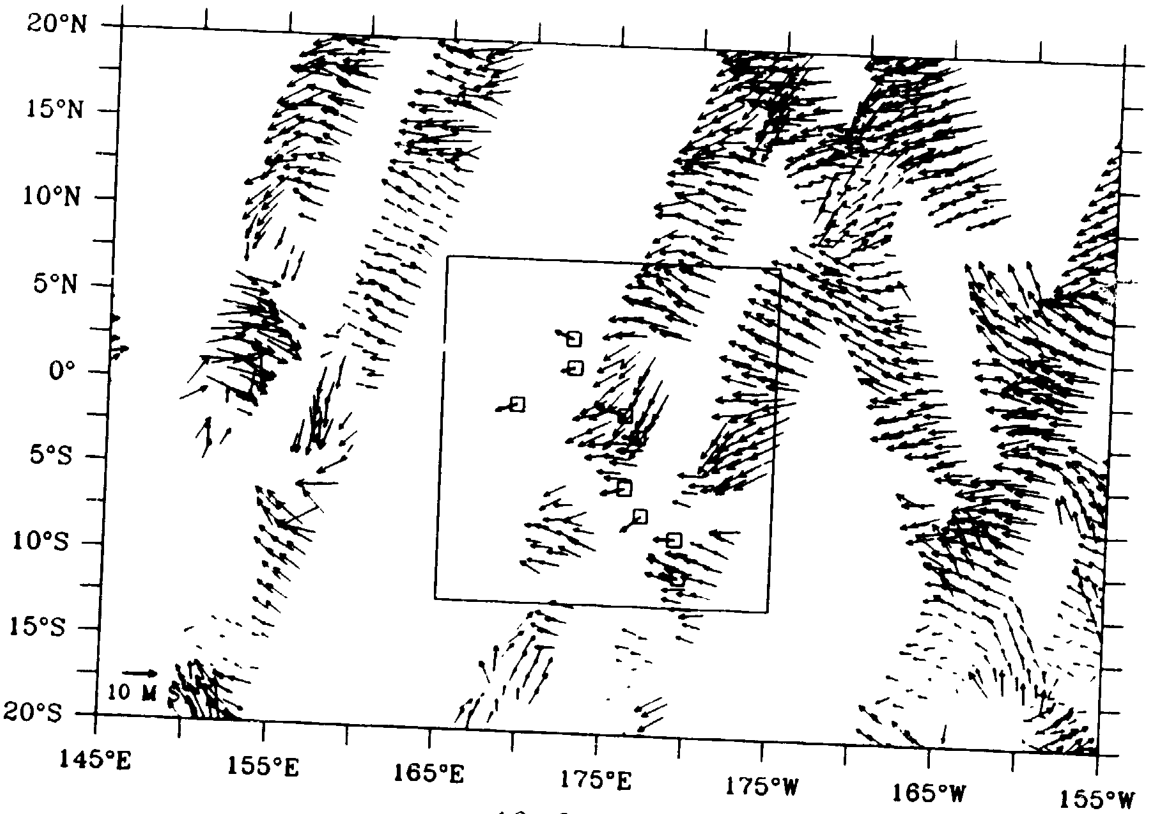

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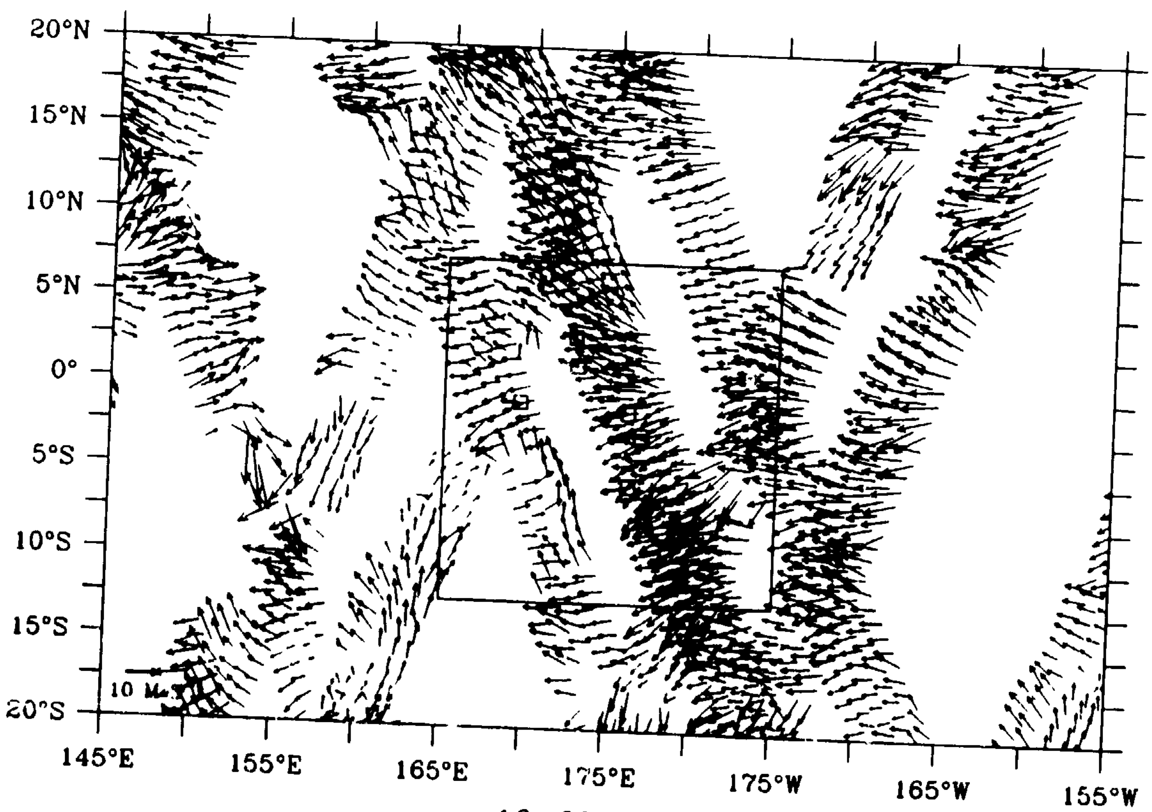

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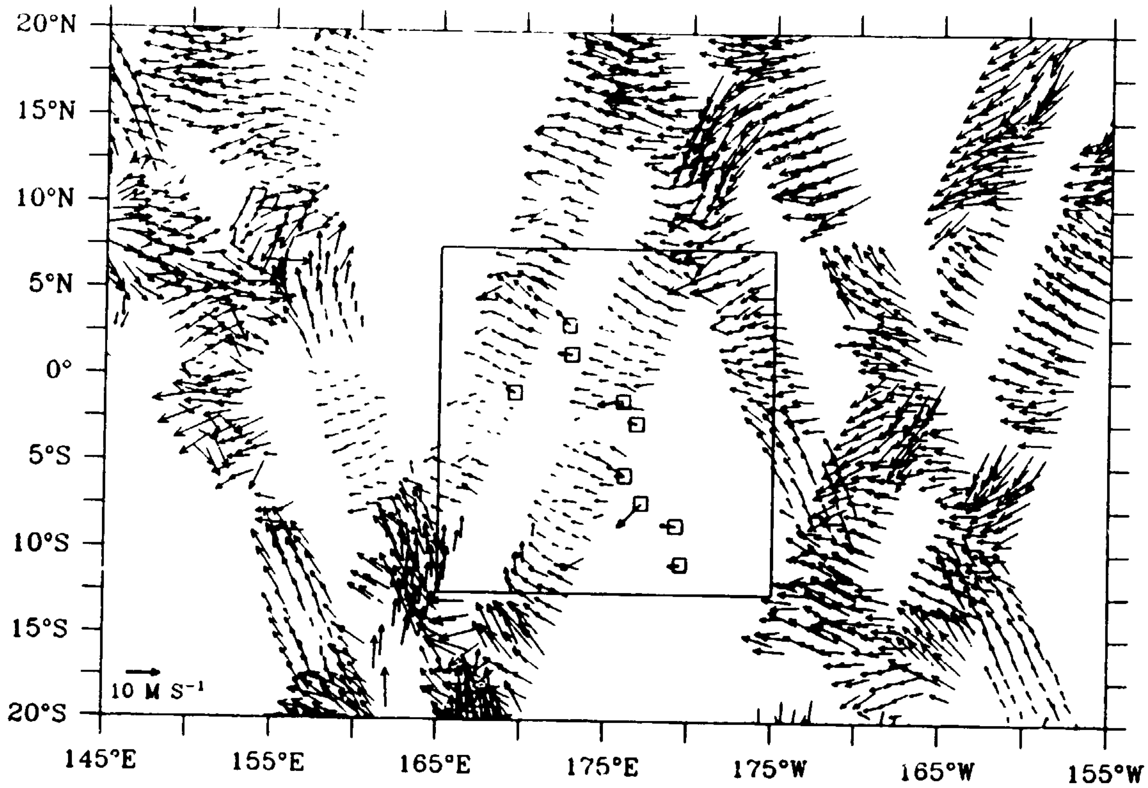
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6. ACKNOWLEDGMENTS

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