Post World War II Trends in Tropical Pacific Surface Trades*

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ABSTRACT

Multidecadal time series of surface winds from central tropical Pacific islands are used to compute trends in the trade winds between the end of WWII and 1985. Over this period, averaged over the whole region, there is no statistically significant trend in speed or zonal or meridional wind (or pseudostress). However, there is some tendency, within a few degrees of the equator, toward weakening of the easterlies and increased meridional flow toward the equator. Anomalous conditions subsequent to the 1972–73 ENSO event make a considerable contribution to the long-term trends. The period 1974–80 has been noted previously to have been anomalous, and trends over that period are sharply greater than those over the longer records.

1. Introduction

The extent to which the climate of the earth is changing under the influence of man's actions has brought new interest in the study of trends in the available surface climate record and of the characteristics of nonanthropogenic climate variability. Much of the best observed natural variability concerns interannual fluctuations. The year-to-year changes in the Indian Ocean monsoon and the tropical Pacific El Niño–Southern Oscillation (ENSO) phenomenon are familiar examples of interannual variability.

Both for phenomenological studies of wind fluctuations, and in order to carry out ocean model studies of the wind stress-forced aspects of the ENSO phenomenon, considerable attention has been given to producing bimonthly and monthly fields of wind stress over the tropical Pacific (Wrytki and Meyers 1976; Goldenberg and O'Brien 1981). Model calculations using the monthly stress fields have produced substantial large-scale trends in their sea level results (e.g. Busalacchi et al. 1983, Fig. 7), driven by trends in the wind stress fields. Because there are so few observations of surface conditions in the tropical Pacific, it is not simple to evaluate the statistical significance of such trends from ship data. Whysall et al. (1987) suggest that there are real trends, and indicate that the trades have been strengthening since the end of WWII. Inoue and O'Brien (1987) have compared trends from wind-driven model calculations with sea level data for the short period between 1974 and 1981, and suggest that the model trends are not inconsistent with the data; their pseudostress analysis indicates that the near-equatorial easterlies were weakening, and indicated no significant trends poleward of about 10 degrees latitude. Both the Whysall et al. (1987) and Inoue and O'Brien (1987) analyses were based on surface-marine shipping reports. However, Cardone et al. (1989) have recently suggested that multidecadal trends in the shipping data could be explained to a substantial extent as a result of changing fractions of Beaufort observations versus uncorrected anemometer observations in the dataset.

In this brief note, trends are presented from a completely independent data source—multidecadal time series of surface winds from tropical islands. Luther and Harrison (1984) presented some preliminary results from island data, discussed aspects of working with such data, and suggested that they could be useful for climate studies; Harrison (1987) has discussed their monthly mean ENSO variations, and Harrison and Luther (1989) presented a variety of variability statistics from these records. The trends in these data had not seemed of sufficient magnitude to merit discussion previously, but they offer an independent perspective on the ship-based results that have attracted recent attention, and so are presented here.

2. Trend results

Figure 1 shows the location of the islands in this dataset with records spanning more than 10 years; 20 of the records span more than 20 years and 8 span more than 30 years. Table 1 lists the years of data in each time series and summarizes the linear least-squares-fit trend results (and the 95% confidence intervals), presented in cm s^{-1} yr^{-1} for wind and m^2 s^{-2}

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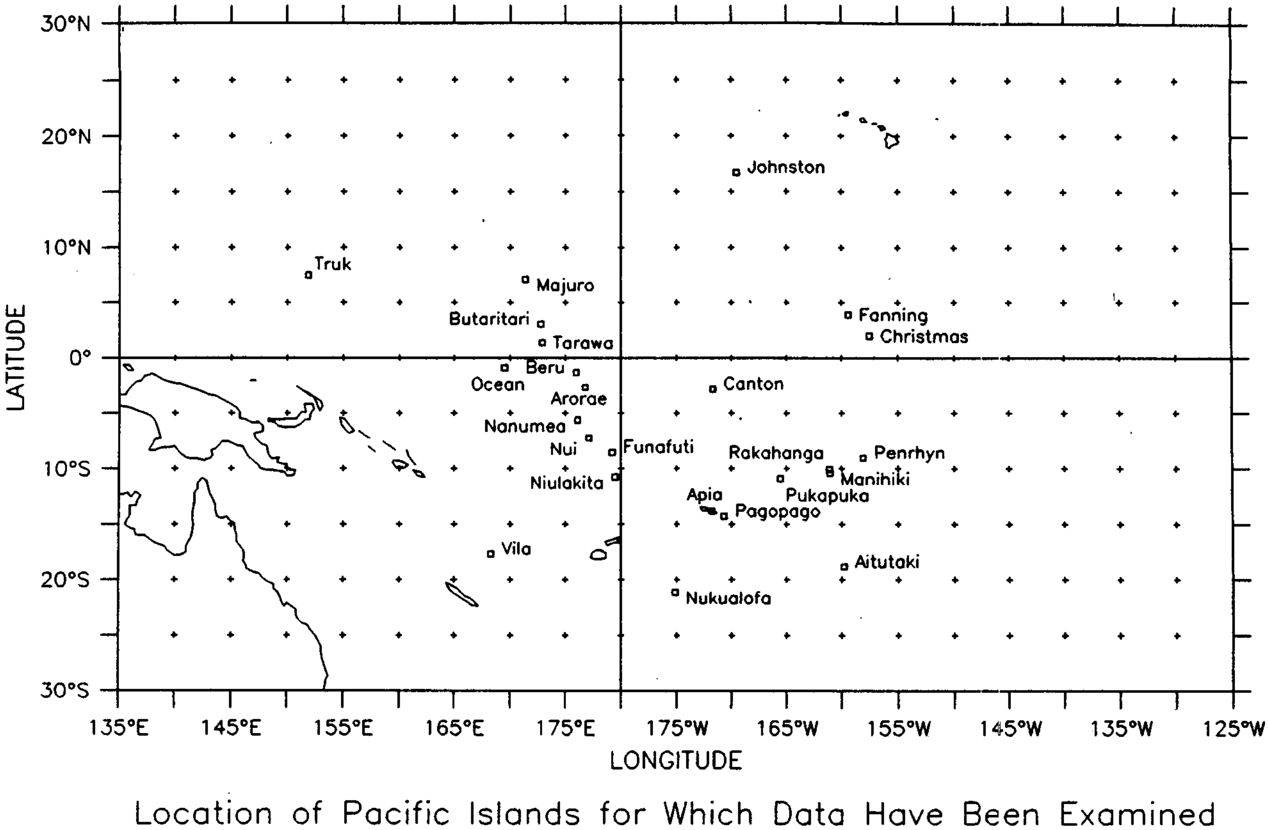

FIG. 1. Locations of islands with surface wind records of at least ten years duration. See Table 1 for the years spanned by the data at each island.

yr^{-1} for pseudostress. About half of the wind records show trends statistically different from zero at the 5% level; only a very few are different from zero at the 1% level (the 99% confidence interval is about 35% larger than the 95% interval). Confidence limits assume that we have more than 30 degrees of freedom in each record, which is unlikely to be controversial for records longer than 20 years; doubling the number of degrees of freedom alters the confidence interval by less than 5%.

Consider first the very largest spatial scale by averaging over all of the islands: the average trend in wind speed is 0.5 cm s^{-1} yr^{-1}, or 0.15 m s^{-1} over thirty years; the average zonal wind trend is 0.1 cm s^{-1} yr^{-1}, or 0.03 m s^{-1} over thirty years. Confidence limits are 1–1.5 cm s^{-1} yr^{-1} for speed and 3–3.5 cm s^{-1} yr^{-1} for zonal wind, so these trends cannot be distinguished from zero. If this average is in some way representative of the trades driven by the large-scale sea level pressure gradient, then there has been no significant trend in these trades.

Of course there is no reason to treat both the northeasterly and southeasterly trades as a single unit. The reader can compute averages over his favorite groupings of islands at will, using Table 1. In the spirit of Fig. 6 of Inoue and O'Brien (1987), we have examined the zonal wind trends as a function of latitude. The islands between 3°N and 3°S each show decreasing easterlies; of the longest records, Tarawa and Beru are distinguishable from zero at the 95% level and indicate trends of about 3 cm s^{-1} yr^{-1}, or 0.9 m s^{-1} over 30 years. Canton and Christmas are shorter records, and indicate somewhat stronger trends, but Fanning has the largest trend, and is of opposite sign. There is also a tendency for increased equatorward flow at these near-equatorial islands. Further poleward there is no consistent sign of the trends.

3. Comments and discussion

Inoue and O'Brien (1987) found zonal pseudostress trends between 1974 and 1981 of 2.0 m^2 s^{-2} yr^{-1} for the region 2°N–4°N by 160°E–140°W, and 1.8 m^2 s^{-2} yr^{-1} for the region 2°S–4°S by 160°E–140°W; trends for the islands over 1974–80 have been evaluated for direct comparison. The islands between 3°N and 7°S each show statistically significant weakening of the easterlies: the zonal pseudostress trend averages about 2.5 m^2 s^{-2} yr^{-1} with a confidence interval of 1.2–2 m^2 s^{-2} yr^{-1}, and the zonal wind trend averages about 30

TABLE 1. Island wind and pseudostress trends.

Island		Wind speed cm s^{-1} yr^{-1}	U wind cm s^{-1} yr^{-1}	V wind cm s^{-1} yr^{-1}	U pseudo m^2 s^{-2} yr^{-1}	V pseudo m^2 s^{-2} yr^{-1}
Aituatki	'57–'81	1.0 ± 1.7	−0.6 ± 2.4	1.8 ± 2.5	−.14 ± .24	**.22** ± .19
Apia	'60–'81	**−4.4** ± 2.3	3.2 ± 3.3	**3.3** ± 1.5	**.27** ± .23	.03 ± .09
Arorae	'54–'85	−0.9 ± 1.1	2.1 ± 2.6	**−2.1** ± 1.1	**.20** ± .19	−.01 ± .08
Beru	'48–'85	−0.7 ± 0.8	**2.9** ± 2.1	**1.7** ± 1.0	**.26** ± .16	**.13** ± .07
Butaritari	'55–'80	**−2.4** ± 1.5	1.8 ± 3.2	**6.5** ± 2.2	**.27** ± .23	**.39** ± .13
Canton	'49–'67	−1.3 ± 2.7	4.4 ± 4.4	**−7.3** ± 3.6	.27 ± .35	**−.43** ± .24
Christmas	'49–'65	**−5.2** ± 2.9	**5.6** ± 3.2	2.3 ± 2.8	**.50** ± .32	**.13** ± .18
Fanning	'49–'80	**7.0** ± 1.5	**−8.5** ± 2.1	**−5.3** ± 2.1	**−.66** ± .17	**−.26** ± .12
Funafuti	'48–'80	**4.8** ± 1.3	−2.7 ± 2.7	1.2 ± 1.8	**−.30** ± .20	.07 ± .12
Johnston	'62–'78	**10.9** ± 2.9	**−11.5** ± 3.9	−3.0 ± 4.3	**−1.6** ± .42	**−.39** ± .36
Majuro	'55–'78	0.5 ± 2.4	0.5 ± 2.9	−1.3 ± 1.6	.00 ± .22	−.10 ± .10
Manihiki	'55–'77	**−4.1** ± 2.3	0.4 ± 3.5	−0.3 ± 2.1	.22 ± .28	−.03 ± .21
Nanumea	'49–'80	**7.0** ± 1.2	−2.2 ± 2.3	0.5 ± 1.7	**−.26** ± .17	**−.68** ± .10
Niulakita	'49–'80	**12.0** ± 1.3	**−8.2** ± 2.6	−1.5 ± 1.4	**−.66** ± .19	**−.12** ± .10
Nui	'49–'85	**3.2** ± 0.9	0.5 ± 2.4	0.6 ± 1.3	−.03 ± .18	.00 ± .08
Nukualofa	'49–'73	0.0 ± 1.3	1.3 ± 2.1	**8.5** ± 1.7	.06 ± .15	.05 ± .09
Ocean	'53–'85	**−3.0** ± 1.0	**3.5** ± 2.6	**1.9** ± 1.2	**.34** ± .17	.07 ± .08
Pago Pago	'66–'78	**6.7** ± 6.0	−3.7 ± 7.9	**−9.0** ± 5.6	−.44 ± .57	**−.45** ± .34
Penhryn	'56–'81	**3.6** ± 1.5	**−3.4** ± 2.9	−2.7 ± 2.7	**−.49** ± .27	**−.21** ± .21
Pukapuka	'56–'80	**−3.7** ± 1.4	2.0 ± 3.1	−0.7 ± 2.1	**.24** ± .22	−.00 ± .14
Rakahanga	'56–'80	**−6.6** ± 1.7	**4.5** ± 2.5	1.1 ± 2.1	**.48** ± .19	.05 ± .15
Tarawa	'48–'80	−1.0 ± 1.3	**3.0** ± 2.2	**−4.7** ± 1.2	**.22** ± .17	−.01 ± .07
Truk	'51–'78	0.8 ± 1.5	−7.7 ± 2.2	1.4 ± 1.8	**−.40** ± .12	−.04 ± .09
Vila	'47–'57	−0.9 ± 4.5	**8.6** ± 5.6	−0.2 ± 3.9	**.53** ± .34	−.06 ± .27

Trends significant at the 5% level are indicated by bold numbers.

cm s^{-1} yr^{-1} with a confidence interval of about 15–20 cm s^{-1} yr^{-1}. Poleward of this equatorial band trends generally are not significant.

The near-equatorial results for 1974–80 zonal pseudostress described by Inoue and O'Brien (1987) thus are supported by the island records, but trends over this period are not representative of the 1950–80 trends. The 1970s, following the 1972–73 ENSO event have been shown previously to be unusual, in that the frequency of surface westerly wind episodes was greater than in the two previous decades (e.g., Luther et al. 1983). To date, this phenomenon has not been explained.

The Whysall et al. (1987) results for 1950–81 indicate strengthening of northeast trades near the equatorial date line with a trend of about 3 cm s^{-1} yr^{-1} and somewhat less rapidly increasing easterlies in the southeast trades in the region of Christmas, Fanning and Canton (their Fig. 4b). They find no statistically significant trends just south of the equator at and west of the date line. The island zonal wind results are completely inconsistent with these findings, as is the work of Inoue and O'Brien (1987) for a shorter period.

The near-equatorial tropical Pacific is known to have very strong interannual variability, as well as variability on a wide range of shorter time scales. It is a difficult system to monitor from scattered and infrequent ship reports. The island data have shortcomings of their own [e.g., Luther and Harrison (1984)]. At present it is difficult to speak definitively about post-WWII trends in the surface winds in this region. But these results, taken together with those of Cardone et al. (1989), clearly indicate that caution should be exercised at present in the interpretation of trends like those discussed by Whysall et al. (1987), as indications of global climate variability.

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