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ON THE REALITY OF CLIMATIC CHANGES IN WIND OVER THE PACIFIC

P. B. WRIGHT

*Max-Planck Institut für Meteorologie, Bundesstrasse 55, D-2000 Hamburg 13, West Germany**

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ABSTRACT

It is important to be aware of systematic errors when using data from ship observations to infer climatic changes. The development of our understanding of systematic errors in sea and air temperatures and cloudiness is reviewed. Many reasons for suspecting similar errors in wind data are noted. Wind data for the tropical Pacific for 1920 1979 are then analysed. Trends to stronger trade winds in both the north and south Pacific, and also large anomalies in the winds in these areas during the Second World War, are found in the data. Quantitative comparisons are made with the associated pressure gradients, and qualitative comparisons with rainfall at Pacific island stations. These series provide no support for the suggestion that the wind changes were real.

KEYWORDS Climatic change Wind Pacific Errors in data Ship observations

INTRODUCTION

Much use is currently being made of long data series based on ship observations. The existence of apparently continuous data sets for a century or more provides an irresistible temptation to analyse them and announce the discovery of climatic changes and trends.

In this paper the development of our knowledge of the sea-surface temperature (SST) and air temperature data sets is described. This development has seen the recognition of an increasing number of causes of systematic error that make the identification of real trends more difficult. It is proposed that the analysis of other fields obtained from ship data be treated with the same scepticism as is now applied to the uncorrected temperature series. As illustration, there is presented here a brief analysis of wind data over the Pacific, in which comparison with pressure data refutes the evidence of trends suggested by the raw wind data.

TYPES OF ERRORS

Even only a shallow investigation of what is known about ship-observed data reveals serious limitations to their use. First, there are errors in individual observations, sometimes very large (Saur, 1963; James and Fox, 1972), and sampling errors due to variable location of observation points from month to month. These errors have been generally recognized, and most analyses have focused on large-scale time-averaged phenomena in which the number of observations is sufficient for the random errors to average out.

Second, there are systematic errors. These are of two types. First, the number of observations has varied with time over several orders of magnitude. The trend has been mainly upwards, but with sharp decreases during the two World Wars (Woodruff *et al.*, 1987). Therefore, climatic statistics for early periods are much less reliable than those based on later years, but conclusions about trends are not affected provided attention is restricted to large-scale phenomena. Second, systematic errors arise due to changes in method of observation, type of instrument, method of coding and so on. The rest of this paper concerns these types of errors.

* Present address: 60 Talfourd Avenue, Reading, RG6 2BP, U.K.

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ERRORS IN TEMPERATURES

The most familiar example of a systematic error is the change from uninsulated bucket to engine-intake method of measuring sea-surface temperature (SST). This source of error was early recognized as being relevant to the question of identifying trends in SST. The first authors to write on this subject were Paltridge and Woodruff (1981). Although they recognized the problem, they believed that it did not apply to their data, and they announced certain patterns of climatic changes. These included a sharp decrease in global mean temperatures at about 1900 to a minimum around 1905–1925, then an increase to a maximum at about 1960.

The next studies, by Barnett (1983, 1984), Wright and Wallace (1983), Folland *et al.* (1984) and Wright (1986) noted similar trends, but they examined the data in more detail, in particular by making comparisons between SST and air temperature (AT). As a result of these studies it became evident that not only was there the bucket/intake question, but also the question of different types of buckets; moreover, several possible sources of errors in AT were also recognized. Barnett (1984) and Folland *et al.* (1984) recognized the problem of changes in temporal distribution of observations, as would occur if observations were made mainly during daylight hours in one period but at all hours during another. The cooling of an uninsulated bucket before the thermometer is read was identified as a type of error that varies with place and season (Wright, 1986).

It has become evident that, the more one delves into these data, the more potential sources of systematic errors one finds. Therefore, even the approach of Folland *et al.* (1984), who tried to make corrections to the SST and AT time series by recognizing some specific causes and using a combination of physical and empirical assessments, may not be adequate. Jones *et al.* (1986) concluded that a full documentation of and correction for all individual sources of systematic error may never be possible. They attempted to correct the errors statistically, by intercomparing series that would not have the same sources of error (SST and AT from ship measurements, and AT from land stations). Their inferred pattern of global temperature trends looks very different from that proposed by Paltridge and Woodruff (1981). Wright (1989) compared SST in the equatorial Pacific with independent rainfall and pressure series that are highly correlated with it, and found support for most of the SST corrections proposed by Jones *et al.* (1986). Further work by Folland and Parker (personal communication) has raised doubts about the Jones *et al.* corrections before 1900, so we are far from hearing the final word on this subject.

Some absurd looking anomalies are evident in the SST and AT data, especially the latter, during part of the Second World War. The solution usually adopted to this problem has been simply to omit this period from analysis, particularly since it had fewer observations than the periods before and since. An investigation by Folland *et al.* (1984) revealed that a simple change in observational practice for AT was probably responsible, and that only the night-time observations were affected; they were thus able to derive approximate adjustments.

ERRORS IN OTHER FIELDS

Much less attention has been given as yet to the other variables in the ship-observed data set, but there is no reason to believe that cloudiness and wind observations, for example, should be immune from the problem of artificial causes of error. Even if there is no obvious cause like a change of instrument, there could be just as many 'hidden' causes, which would become apparent only when inhomogeneities in empirical analyses led one to look for them.

An initial look at cloudiness data (Wright, 1986) revealed an apparent trend that for physical reasons could not be regarded as real. Attempts to discover the cause were unsuccessful, but led to the discovery of other potential sources of error involving coding practices. Inhomogeneities in the amount of low cloud found by Warren (reported by Wright, 1986) were probably caused simply by changes in coding practices. These results will, it is hoped, warn future analysts to be wary of making claims about climatic changes in cloudiness.

The general lesson to be learned from these studies is that there are so many potential sources of error in data based on shipboard observations that, if a systematic change is found, one should assume initially that the cause is artificial. Only if the same change can be found in an independent data set not subject to the same sources of error, can one be confident in believing that there is evidence of a real climatic change.

ANALYSES OF WIND DATA

There are many reasons why reported wind speeds might not be homogeneous. First, there have been changes in the method of estimating Beaufort wind force, from state of sail to sea state to a mix of subjective and instrumental measurements (Peterson and Hasse, 1987). Second, the conversion from Beaufort to metres per second is itself subject to some uncertainty, and two different methods have been recognized (Isemer and Hasse, 1987; Woodruff *et al.*, 1987). Third, the ability to estimate winds could vary between day and night, especially in wartime when lights were forbidden. Fourth, Ramage (1982) has pointed out that ships in earlier days spent more time in regions of light winds, and so a relatively greater proportion of light winds would have been reported. Fifth, the success of ship routing techniques implies that, in recent years, ship tracks have been biased towards regions where the wind is favourable to their travel. Ramage (1982, 1984, 1987) has noted yet more reasons to expect discontinuities in the ship wind-data series. No one aware of these problems and familiar with the history of the temperature studies would accept at face value reports of trends, or anomalous periods during wartime, gained solely from evidence of shipboard wind measurements.

Recently Whysall *et al.* (1987) published an analysis of wind data based on the Meteorological Office ship data set. Although they mentioned some specific causes of error, they believed that these did not apply to their data, and they announced certain patterns of climatic changes. These included a trend towards stronger trade winds in the Pacific from 1920 to 1980, and a period of much weaker winds during the Second World War.

The paper presents a similar analysis of wind data. It is first hypothesized that any systematic inhomogeneities are artificial, then it is attempted to disprove this hypothesis by comparison with independent pressure and rainfall data.

DATA

Wind data derived from the comprehensive ocean–atmosphere data set (COADS) (Woodruff *et al.*, 1987), which is based on mainly the same original observations as the Meteorological Office set, were used. Monthly anomalies were calculated relative to the mean for 1950–1979 in 4° latitude by 10° longitude boxes, omitting boxes with less than four observations in an individual month. Anomalies were averaged over the two regions 6°N–26°N, 150°E–130°W and 2°S–22°S, 160°W–90°W; these are approximately the regions used by Whysall *et al.*

Pressure anomalies from the same source were used and analysed similarly. The following differences were formed: (i) the 'northern' difference 30°N–22°N minus 10°N–2°N, both over 150°E–130°W; and (ii) the 'southern' difference 2°N–6°S minus 18°S–26°S, both over 160°W–90°W. Data from the 'southern' difference were missing for many months during 1937–1945. These pressure differences represent the north minus south pressure gradient across the two regions used for the wind indices.

Finally, rainfall data at stations in the Pacific were obtained from the National Center for Atmospheric Research (NCAR) 'World Weather Records' set. These were transformed by taking percentages of cube roots of monthly rainfalls, then averaging the monthly percentages over each calendar year.

METHOD

According to physical theory, the zonal component of wind at locations away from the Equator should be proportional to the local north–south pressure gradient. Therefore, any departure from a linear relationship between wind anomaly and associated pressure difference anomaly would suggest an error in one or the other series. Since both the wind and the pressure data used here are from ship observations, they are both liable to systematic errors; however, the use of pressure *differences* implies that at least one type of pressure error, that which involves large regions uniformly, will cancel out and not affect the analysis.

For each of the two regions the wind anomaly index was compared with the corresponding pressure gradient index; the two series were correlated over three subperiods each of which appeared to be homogeneous, and the latest subperiod (1965–1979) was used to determine a regression relationship of zonal wind as a function of pressure gradient. From this equation one can make estimates of the expected zonal component in the other subperiods, and compare them with the observed values.

The rainfall data were used qualitatively to provide further evidence.

RESULTS

Annual means of the wind indices (Figure 1a and 1c) indicate for both regions a change in level between pre- and post-war periods, and also a trend towards increased easterlies in the southern region since 1950. These are similar to the trends reported by Whysall *et al.* (1987). They also conform with the report by Ramage (1987) of increases of mean scalar wind speed from 1920–1940 to 1960–1980 by about 1 m s^{-1} in the COADS. The pressure indices (Figure 1b and 1d), however, exhibit no appreciable trends.

The war period exhibited some exceptionally large anomalies; those for the northern region in 1944 and 1945 are not plotted because they were far off the scale at $-7{\cdot}4$ and $-13{\cdot}7$ m s^{-1} respectively. The anomalies for individual months (Figure 2) clearly indicate that the statistics for that period were enormously different from those of periods before and since, Whysall *et al.* also found very large anomalies in their wind data for 1942–1945, but in the northern region, opposite signs from ours. Again, no similar variations are apparent in the corresponding pressure series.

Consider first the longer-period trends. Table I shows how each wind index is related to the pressure difference north minus south across the relevant region. For the northern region the correlation of monthly values since 1950 is very high, confirming the strong physical relationship between wind and pressure gradient as well as the validity of the data for this purpose. According to the regression equation, the pressure anomaly in 1920–1935 would imply an anomaly in U of only about 0·2 m s^{-1}, compared with the observed value of 1·1 m s^{-1}. Since the pressure difference is relatively constant, and since spatially uniform pressure errors will not affect the analysis, we may reasonably suspect that this difference represents a wind anomaly due to non-

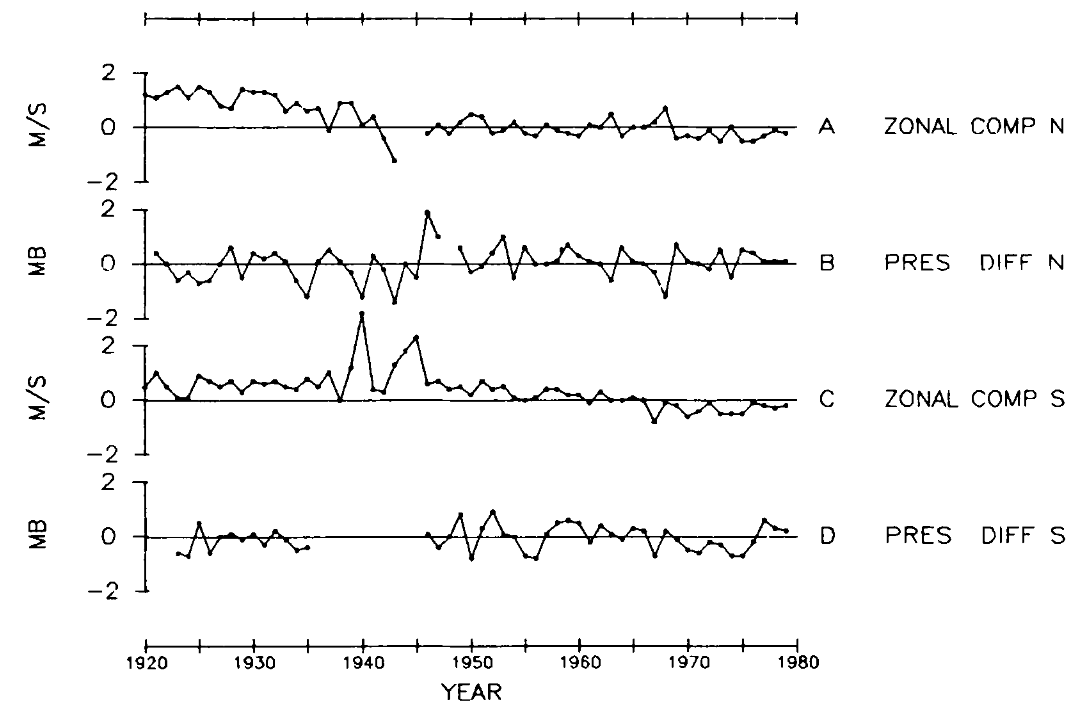

Figure 1. Annual mean anomalies, 1920–1980, of zonal wind components and pressure gradients relative to 1950–1979 means. (a) Zonal wind, north region, mean $= -5{\cdot}4$ m s^{-1}; (b) pressure gradient, north region; (c) zonal wind, south region, mean $= -5{\cdot}0$ m s^{-1}; (d) pressure gradient, south region

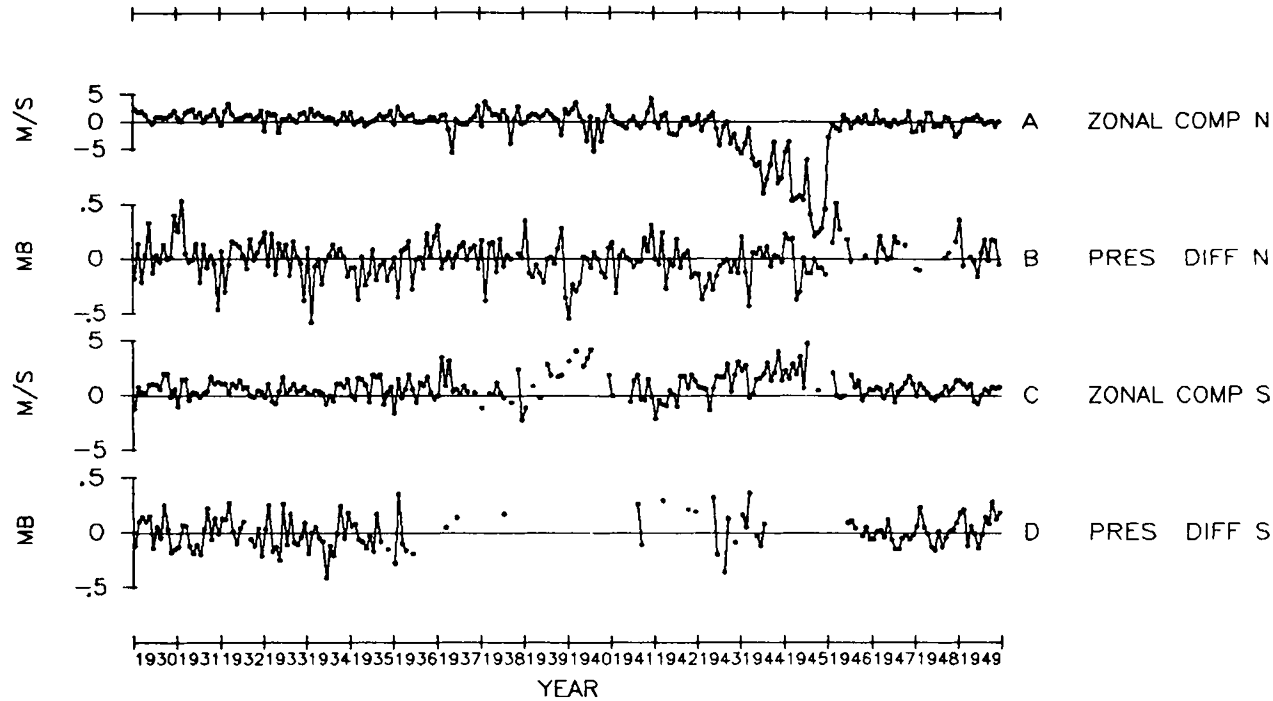

Figure 2. Monthly values for 1936–1949 of same indices as in Figure 1

Table I. Relationships between wind (U) and pressure gradient (ΔP) anomalies based on monthly data

	1920–1935	1950–1964	1965–1979
Northern region			
Correlation of U and ΔP	−0·35	−0·70	−0·82
Mean U (m s^{-1})	1·1	0·0	−0·1
Mean ΔP (mb)	−0·4	0·1	0·1
Regression equation for 1965–1979: $U = -0{\cdot}47\ \Delta P - 0{\cdot}1$			
Southern region			
Correlation of U and ΔP	0·61	0·57	0·68
Mean U (m s^{-1})	0·6	0·2	−0·3
Mean ΔP (mb)	0·0	0·1	−0·1
Regression equation for 1965–1979: $U = 0{\cdot}36\ \Delta P - 0{\cdot}2$			

climatic causes. For the southern region the correlation is a little weaker but consistent back to 1920, implying data of uniform quality for this region. In this case the pressure changes would imply that there should have been almost no trend in the mean wind, by contrast with the 0·9 m s^{-1} indicated in the data.

This comparison with pressure implies that most of the trend in the wind data is due to artificial causes. Ramage (1987), in a similar analysis of wind and pressure in the China Seas region, also concluded that an increase of reported scalar wind of about 1 m s^{-1} from 1900–1939 to 1950–1979 was artificial.

Figure 3 shows that there were no marked trends in the rainfalls of the regions shown, although there are suggestions of trends in the series for Honolulu and Tahiti.

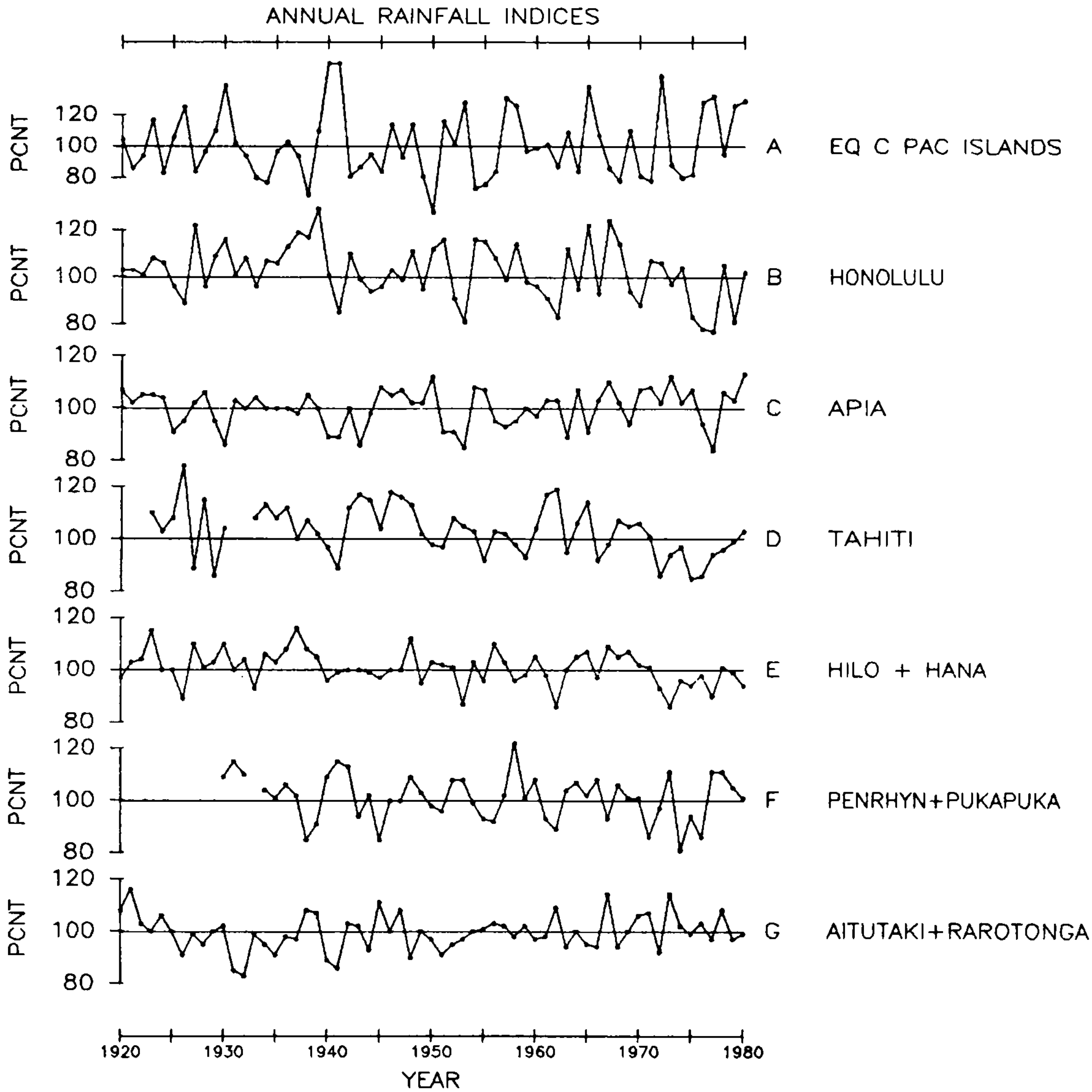

Figure 3. Annual rainfall indices in seven regions of the Pacific, 1920–1980

Consider next the anomalies during the 1940s. Given the magnitude of these anomalies, and their coincidence with the wartime period, it seems quite inappropriate to believe that they imply a real climatic fluctuation. Such an anomaly would have represented a complete cessation of the mean trade winds in some areas, and an excessive strengthening in others, and this would have had a profound effect on the weather in many places. No such effect is evident in the rainfall in any of the Pacific regions shown in Figure 3. Whysall *et al.* suggested that a gross anomaly of wind in the Pacific really occurred during 1940–1945. However, there is no evidence of such an event in the rainfall series, except that the series for the central Pacific islands (Figure 3a) reflects the well-known strong El Niño event of 1939–41. The pressure gradient index for the northern region (Figure 2b) also shows no evidence of abnormal behaviour.

It must be concluded that the winds reported during the Second World War period were greatly distorted estimates of the true winds. One could surmise many plausible reasons for such an occurrence. One suggestion is as follows: under the emergency, the observing staff might have been taken on without the usual training, and therefore did not estimate wind speed by the conventional techniques. The large differences between the results of Whysall *et al.* and those of the present paper could be explained on the basis that the two sets of observations were based on data from different nations, whose practices were different. Such problems are much more likely to have occurred during wartime periods when there was less communication between nations, and for which data are less likely to have reached the same archives. At any rate, there is an abundance of reasons for believing that the observed anomalies, some very large, are artificial.

CONCLUSIONS

Trends and large anomalies in zonal winds in the Pacific have been identified in the COADS ship-observed data set, similar to those identified by Whysall *et al.* in the overlapping Meteorological Office data set. Comparison of these data with pressure and rainfall data does not support the suggestion that the trends during 1920–1980 and the large anomalies during the Second World War were real. No specific cause of particular inhomogeneities has been identified, but many potential causes of inhomogeneities in these wind data are known. It is inferred that the supposed trends and anomalies are artificial. Whether there have been any, much smaller, real trends or fluctuations in winds over the Pacific must await more comprehensive analyses.

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