Alongshore Wind Stress, 1953-1984: Correction, Reconciliation and Update Through 1986

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Abstract

Corrected values are presented for the monthly series of Peruvian alongshore stress presented in the previous volume of this series. The series is updated through 1986. The faulty "old" and corrected "new" series are compared and found to have very similar properties. It is concluded that studies based on the "old" series will not be significantly in error.

Resumen

Se presentan los valores corregidos del esfuerzo del viento a lo largo de la costa peruana, para las series mensuales dadas en el Volumen previo a este. La serie ha sido actualizada hasta 1986. Se compara la serie "antigua" defectuosa con la serie "nueva" corregida, encontrándose que ambas tienen propiedades muy similares. Se concluye que los estudios basados en la serie "antigua" no contienen error significativo.

Introduction

Bakun (1987) presented monthly indicator series for a number of environmental processes affecting the habitat off Peru. An error has been discovered in the computer program used to generate one of the reported series, that of the alongshore component of wind stress on the sea surface. Here we present corrected values for that particular series and also update the series through 1986 (Table 1).

Alongshore wind stress is one of the most important forcing functions for dynamic processes in the coastal environment. For periods of variation longer than a half-pendulum day (2.9 actual days at 10° latitude), the offshore transport which is directly driven by the wind (the offshore Ekman transport) is directly proportional to the equatorward alongshore wind stress, the constant of proportionality ($\sim 3.95 \times 10^4$ sec. for the latitude range of this particular series) being the reciprocal of the Coriolis parameter. To the extent that the flow divergence at the coast due to offshore surface transport is not balanced by convergence of alongshore flow, the water transported offshore is replaced by upwelling of deeper waters to the surface. Thus, variability in alongshore stress is reflected in variability in intensity of locally wind-driven coastal upwelling. Interyear variability in alongshore stress, often expressed either in terms of offshore Ekman transport or in terms of an "upwelling index", has been found to correlate with recruitment variability in a number of neritic fish populations (Bakun and Parrish 1980; Shepherd et al. 1984; Bakun 1985).

The computations and procedures employed in generating the updated corrected series (Table 1) are those outlined by Bakun (1987), except that the data for 1985-86 is from the COADS dataset rather than from the TDF-11 dataset.

Table 1. Alongshore component (positive equatorward) of wind stress on the sea surface. Units are dynes per square centimeter. Values in this table multiplied by the factor 3.95 yield offshore Ekman transport in cubic meter per second across each meter width.

Tabla 1. Componente a lo largo de la costa (positivo con dirección ecuatorial) del esfuerzo del viento sobre la superficie del mar. Las unidades se dan en dinas por centímetro cuadrado. Los valores de esta Tabla al multiplicarse por 3.95 dan como resultado el transporte Ekman en metro cúbico por segundo por cada metroo de línea costera.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1953	.33	.27	.37	.79	.70	.29	.63	.32	.42	.46	.55	.24
1954	.21	.37	.09	.41	.46	.40	.46	.73	.76	.21	.32	.19
1955	.32	.14	.50	.18	.54	.38	.41	.76	.57	.60	.54	.10
1956	.15	.23	.59	.70	.71	.44	.59	.52	.57	.47	.40	.39
1957	.27	.43	.62	.71	.47	.66	.83	.51	.64	.49	.40	.51
1958	.36	.38	.40	.51	.48	.41	.47	.67	.45	.42	.23	.34
1959	.30	.26	.34	.37	.26	.55	.33	.67	.45	.38	.27	.20
1960	.21	.24	.36	.42	.46	.38	.51	.48	.45	.43	.29	.32
1961	.19	.22	.34	.41	.59	.41	.57	.42	.45	.58	.33	.27
1962	.38	.29	.41	.44	.43	.49	.52	.44	.53	.44	.45	.23
1963	.29	.34	.53	.40	.50	.28	.46	.40	.63	.62	.45	.32
1964	.43	.38	.44	.57	.52	.50	.53	.61	.64	.51	.31	.36
1965	.26	.35	.34	.46	.79	.50	.53	.70	.76	.55	.45	.43
1966	.53	.53	.42	.61	.51	.53	.64	.65	.53	.48	.24	.22
1967	.34	.32	.25	.26	.33	.62	.48	.62	.62	.63	.39	.50
1968	.13	.35	.32	.30	.29	.55	.76	.63	.57	.53	.45	.50
1969	.26	.23	.39	.48	.39	.74	.49	.59	.52	.37	.26	.34
1970	.29	.11	.35	.50	.49	.45	.49	.45	.41	.47	.38	.26
1971	.16	.32	.29	.50	.35	.60	.39	.69	.53	.60	.38	.40
1972	.25	.27	.45	.47	.35	.58	1.00	.70	1.14	.44	.35	.65
1973	.52	.34	.60	.60	.57	.47	.58	.98	.85	.60	.49	.33
1974	.28	.35	.39	.57	.60	.56	.61	.54	.65	.60	.59	.42
1975	.34	.31	.59	.51	.63	.53	.56	.77	.63	.46	.32	.31
1976	.19	.15	.42	.62	.61	.48	.50	.57	.70	.60	.54	.48
1977	.28	.46	.34	.49	.40	.56	.80	.69	.42	.41	.50	.46
1978	.33	.43	.54	.58	.50	.59	.53	.59	.63	.48	.45	.41
1979	.42	.45	.48	.59	.91	.76	.55	.70	.67	.56	.48	.43
1980	.39	.40	.42	.42	.73	.46	.81	.57	.63	.56	.42	.41
1981	.43	.25	.41	.46	.45	.71	.64	.52	.72	.37	.49	.34
1982	.32	.42	.52	.46	.57	.76	.76	.54	.80	.76	.84	.57
1983	.61	.55	.39	.63	.65	.91	.70	.56	.62	.51	.33	.20
1984	.23	.56	.73	.27	.70	.79	.54	.78	.53	.51	.70	.47
1985	.27	.27	.16	.65	.48	.38	.50	.50	.65	.36	.52	.34
1986	.35	.23	.30	.41	.44	.56	.58	.68	.85	.75	.74	.44

Comparison and Reconciliation of the Two Series

Resolution of the alongshore component of the wind stress, τ_a, is according to

$$\tau_a = \alpha \tau_y - \beta \tau_x \qquad \text{... 1)}$$

where τ_y and τ_x are the respective northward and eastward stress components; $\alpha = \cos\phi$ and $\beta = \sin\phi$, where ϕ is the angle, counterclockwise from true north, of the large-scale coastline trend. For the Peruvian coast a compass direction of 332° ($\phi = 28°$) is chosen as the characteristic large scale coastline trend (i.e., $\alpha = 0.8829$, $\beta = 0.4695$).

In producing the series reported by Bakun (1987), the value 0.8829, appropriate to α, was also erroneously assigned to β. Since the wind stress off Peru is generally from the southwest (Bakun and Parrish 1982), τ_x would generally have a negative value. Thus the magnitude of the monthly estimate of τ_a would tend to have been amplified by the error. The computation of the onshore component of the wind stress and of the "wind cubed" index (Bakun 1987) are unaffected by this error.

Thus the power spectra of the "old" series from Bakun (1987) generally has higher values than the "new" corrected series (Fig. 1a). However, note that the shape of the spectra are quite similar, with high peaks at the annual frequency and the familiar "red noise" spectral shape at the low frequency end. Note also that the coherence (Fig. 1b) between the series is very high, being nearly 1.0 over the spectral peaks and falling somewhat lower only in spectral "gaps" where very little of the variance of the series is found. Also there is essentially no phase difference between the two series over the entire spectral range (Fig. 1c). Fig. 1 shows that the two series should be nearly equivalent for most applications, except in terms of magnitude.

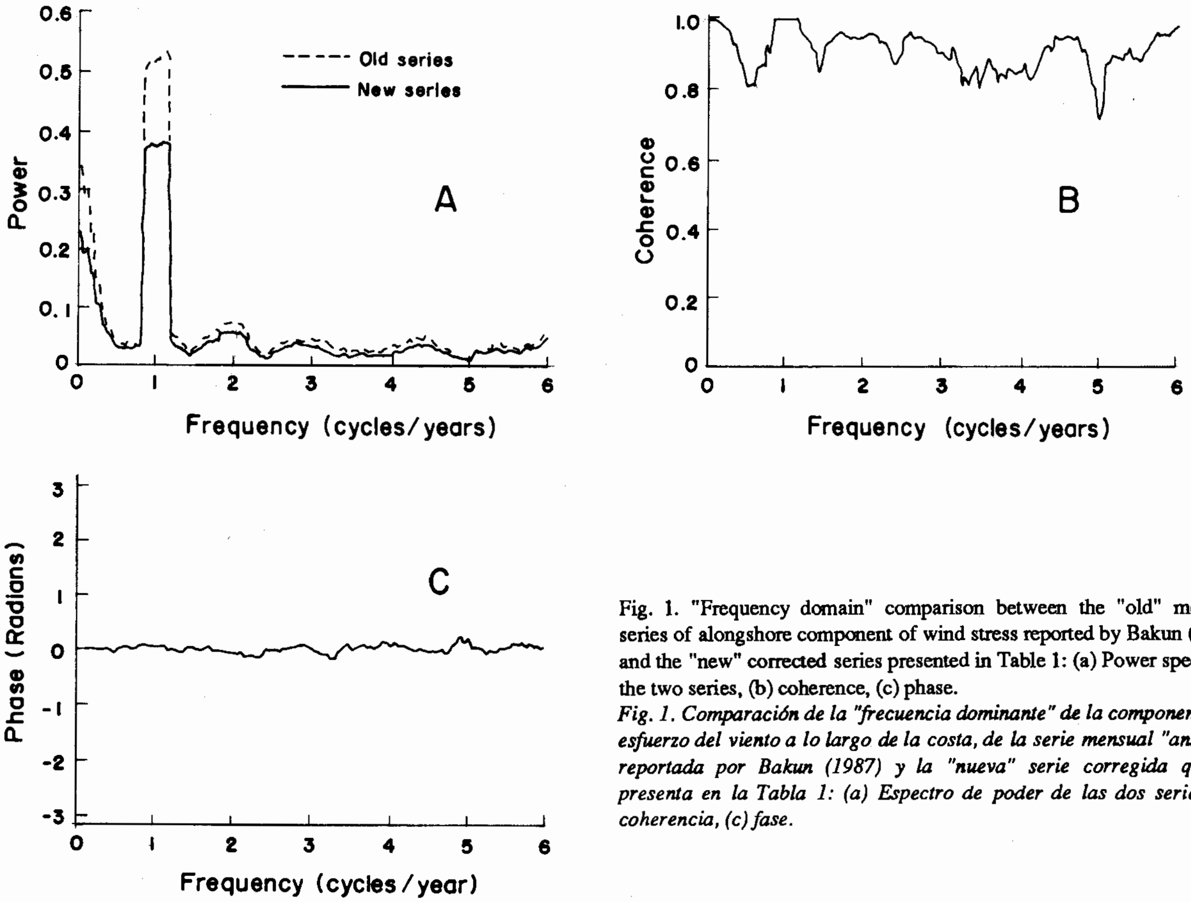

Fig. 1. "Frequency domain" comparison between the "old" monthly series of alongshore component of wind stress reported by Bakun (1987) and the "new" corrected series presented in Table 1: (a) Power spectra of the two series, (b) coherence, (c) phase.

Fig. 1. Comparación de la "frecuencia dominante" de la componente del esfuerzo del viento a lo largo de la costa, de la serie mensual "antigua" reportada por Bakun (1987) y la "nueva" serie corregida que se presenta en la Tabla 1: (a) Espectro de poder de las dos series, (b) coherencia, (c) fase.

For example, the seasonal pattern is very similar (Fig. 2), as are the major interannual features in the two series (Fig 3). Both series indicate seasonal maxima in alongshore stress during austral winter (peak in September) and minima in summer (lowest in January). Both series show increases in alongshore stress associated with El Niño episodes and some indication of a general linear upward trend from the mid-1950s to 1982-83.

For readers who may be more comfortable with correlation coefficients than with coherence spectra, regressing the "old" series on the "new" series yields a correlation of r = .975 and a regression line slope of b = 1.14. Transforming the two series to "anomalies", by subtracting the

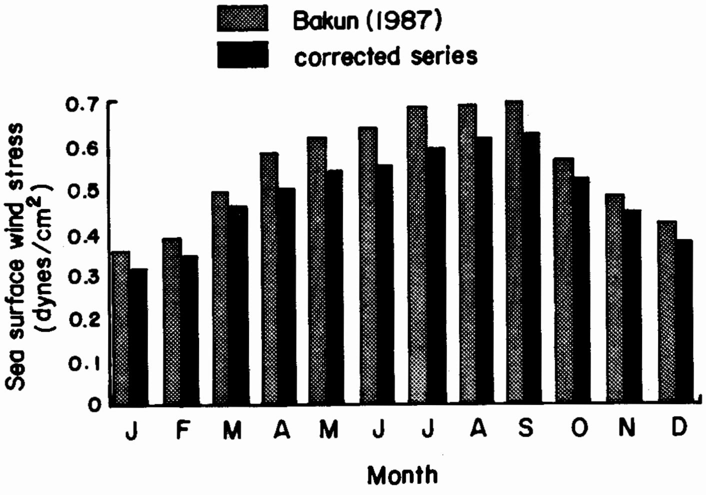

Fig. 2. Seasonal pattern (long term 1953-84 mean monthly values) of the "old" monthly series of alongshore component of wind stress reported by Bakun (1987) and of the "new" corrected series presented in Table 1.

Fig. 2. Patrón estacional (promedios mensuales a largo plazo 1953-84) de la serie "antigua" de la componente del esfuerzo del viento a lo largo de la costa reportada por Bakun (1987) y la "nueva" serie corregida presentada en la Tabla 1.

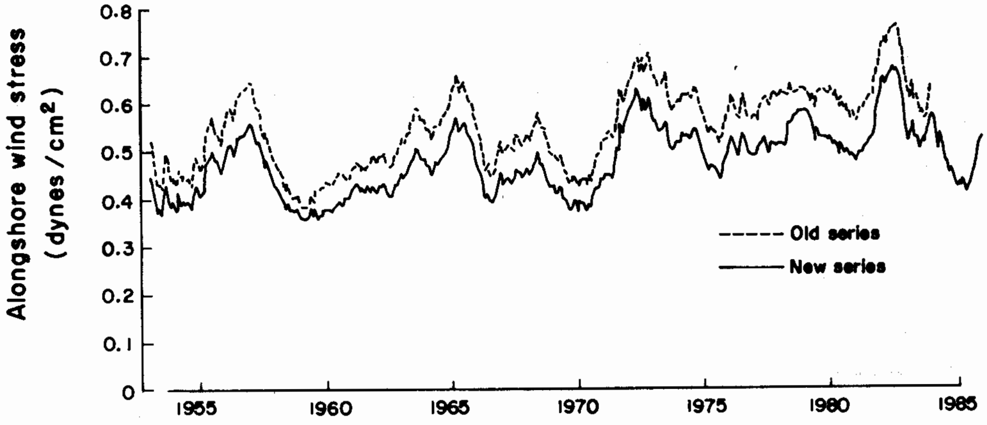

Fig. 3. Low-frequency nonseasonal variations: 12-month running means of monthly time series values of the "old" monthly series (dashed line) of alongshore component of wind stress reported by Bakun (1987) and the "new" corrected series (solid line) presented in Table 1.

Fig. 3. Variaciones de baja frecuencia no estacionales: promedios moviles de 12 meses de los valores de la "antigua" serie mensual (línea punteada) de la componente del esfuerzo del viento a lo largo de la costa, reportada por Bakun (1987) y la "nueva" serie corregida (línea solida) presentada en la Tabla 1.

appropriate 1953-84 long term monthly mean from each monthly value, yields r = .962 and b = 1.12. Removing the seasonal variation and the long term linear trend by "12th-differencing" each series (subtracting from each value the value for the same month one year earlier) yields r = .953 and b = 1.09. The regression line directly intersects the origin (intercept = 0.00) in all three cases.

Bohle-Carbonell (this volume), in examining the fractal dimensions of several series related to the anchoveta fisheries, uses the Bakun (1987) series. As discussed in Mendelssohn (this vol.), there is a close relationship between fractal dimension and fractal differencing in time series. Statistical estimates of the fractional differencing parameter *d* are determined from properties of the observed and theoretical spectrum. As the "old" and "new" series have similar spectra, there should be little change in these estimates, and the use of the "new" series should not affect Bohle-Carbonell's conclusions. (In fact, the estimate of fractional differencing for the "old" series is *d = .2212,* while for the "new" series it is *d = .2857,* see Mendelssohn (this vol.) for details).

Cury and Roy (1989) estimate optimal environmental windows for the Peruvian anchoveta, as well as for species from other eastern boundary current regions, using a turbulence index (wind speed cubed) as the environmental variable. Their study is unaffected by this correction, as they use the Trujillo series of Mendo et al. (1987). It is expected that other studies that may have used the earlier series will be similarly unaffected to any substantial degree.

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Cover: False color satellite images of the Peruvian upwelling system taken during a 4-day period (5-8 May 1985) with a well developed area of cold waters along the Peruvian coast (front cover) and during a 3-day period (2-4 March 1986) when warm oceanic waters invaded the nearshore habitat of anchoveta (back cover). (Images: courtesy of the US National Oceanic and Atmospheric Administration).

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