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Local winds south of Sierra de Misantla (Mexico), and their statistical relationships with 500 mb circulation

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RESUMEN

Se aplican modelos de regresión lineal bivariada para estudiar la relación entre vientos locales y características de la circulación a 500 mb. Los resultados indican que ni la dirección ni la rapidez del viento a 500 mb influyen significativamente en la circulación superficial. En cambio, factores como el periodo del día, la nubosidad, la estabilidad atmosférica y el gradiente térmico superficial en la horizontal, influyen notoriamente en la rapidez y dirección de los vientos en la región estudiada.

PALABRAS CLAVE: Circulacion local, regresion lineal bivariada.

ABSTRACT

Bivariate regression models for the relationship between local surface wind and the circulation at 500 mb. are proposed. Results indicate that wind direction or wind speed at 500 mb are not significantly related with surface wind. However, factors like day or night time, cloudiness, atmospheric stability and horizontal temperature gradients at the surface have a strong influence on air flow.

KEYWORDS: Local circulation, bivariate linear regression.

INTRODUCTION

For weather or air pollution forecasting it is important to know the relationship between upper wind circulation and surface winds. For the area south of Sierra de Misantla (Mexico), Cervantes (1987) and Morales *et al.* (1989) used linear regression of surface wind direction on time, wind speed and wind direction at 850 mb, synoptic situation, atmospheric stability, existence of thermal inversions up 850 mb and cloudiness. The correlation coefficients obtained were high, but the sample sizes were small.

In this paper quantitative relationships between surface wind and 500 mb circulation are given, using the approach of Shreffler (1982), Kau (1982), Johnson *et al.* (1986), and Ryan (1977). Local surface circulation forecasts are obtained in terms of synoptic weather forecasts.

THE DATA

In the study area there are five climatological stations. The basic data set includes hourly wind and temperature measurements at 10 m above ground level. In Veracruz Harbor, radiosondes are launched at 6 and 18 hours local time (Figure 1). In this paper one year of information (1984) with a total of 233 cases was used.

Wind data were represented as bidimensional vectors (Mardia, 1972). Mean surface wind directions and speeds at night (3 to 8 hours) and during the daytime (15 to 21 hours) were computed for all stations. The correlation coefficient between wind speed and wind direction for each station was obtained. The variance of this correlation was obtained by the jackknife method (Efron, 1981; Johnson and Wehrly, 1977; Oseguera, 1989). Exploratory analysis using confidence intervals suggests that the computed means were representative and that correlation coefficients were significant at 0.05 significance level (see Table 1).

This exploratory analysis also showed that the nighttime means were very different from the daytime means. Night winds (land breezes) are weaker than daytime winds (ocean breezes), because larger temperature gradients and atmospheric stability during the day promote vertical mixing, while nocturnal radiative cooling stratifies the air in the lower layers (Jáuregui, 1984).

There is an annual variability of the surface circulation (Figures 1 and 2). The larger daytime speeds occur during May, July, September and November with northerly wind components, and the smaller ones occur in March, June, August and October with easterly wind components (Jáuregui, 1984).

REGRESSION MODELS

A bivariate model for studying wind directions (Y_1) and wind speeds (Y_2) was used. The independent variables were:

X_1: Wind direction at 500 mb (in azimuthal degrees),

X_2: Time (0 for day time, 1 for night time),

X_3: Atmospheric stability: (1, absolute stability; 2, conditionally stable; 3, neutral; 4, conditionally unstable; 5, absolutely unstable).

X_4: Wind speed at 500 mb (m/s),

X_5: Synoptic situation in study area (1, neutral point on Gulf of Mexico which induces relatively low wind speeds in study area; 2, low pressure on Gulf of Mexico affecting the study area; 3, high pressure on Gulf of Mexico; 4, cold front, i.e. northerner near study area.

X_6: Cloudiness (in octas),

X_7: Temperature difference between Laguna Verde (coastal station) and Hornitos (inland station).

The equation of the general linear model is (Tim, 1975; pp. 185-190):

$$Y = XB + E \qquad (1)$$

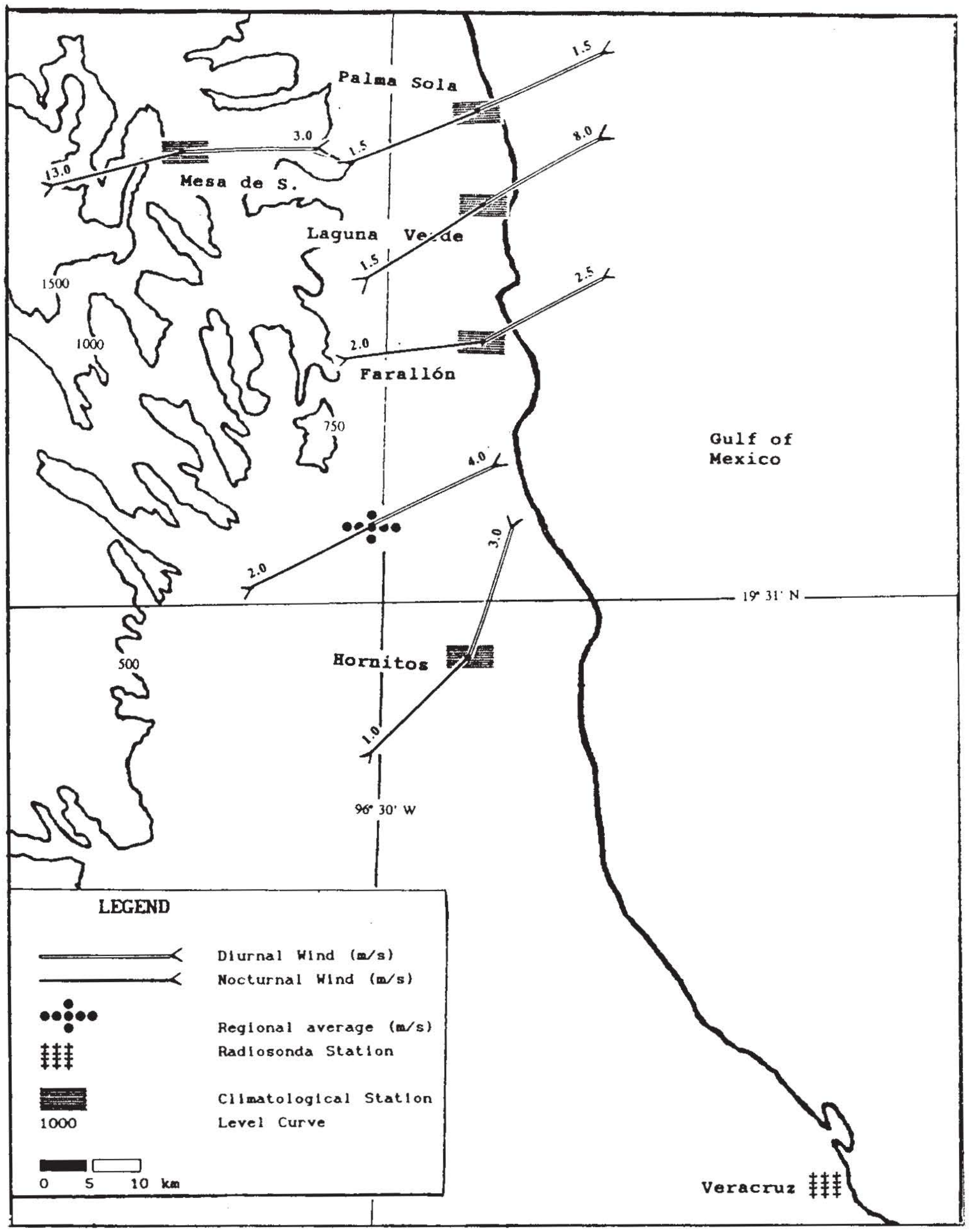

Fig. 1. Resultant winds (day and night), for July 1984.

where $B = [B(1)!B(2)]$ is the unknown parameter matrix. By least squares the estimated parameter matrix is

$$B = (X'X)^{-1} XY \tag{2}$$

Assuming independence of residuals:

$$E = [E(1),E(2),...E(n)] \tag{3}$$

Each E_t is assumed to be normally distributed about zero with a common variance-covariance matrix.

We have fitted the data to this model and some diagnostics were conducted. The results have been reported in a residual exploratory analysis (Ojeda, 1988).

The influence of different variables on the observations was explored assuming that Y_i is an influence point if $Y_i > (2p/n)$, where n is the number of cases and p is the number of independent variables plus one (Hocking, 1983).

Figures 3 and 4 are plots of residuals for the wind speed and wind direction. Notice that the wind speed is accurately predicted as the variance of residuals is small, although for wind speeds greater than 2.5 m/s the variance rises indefinitely. This contradicts the hypothesis of ordinary least squares.

In order to correct this problem, the possible influence points were eliminated but the results did not improve

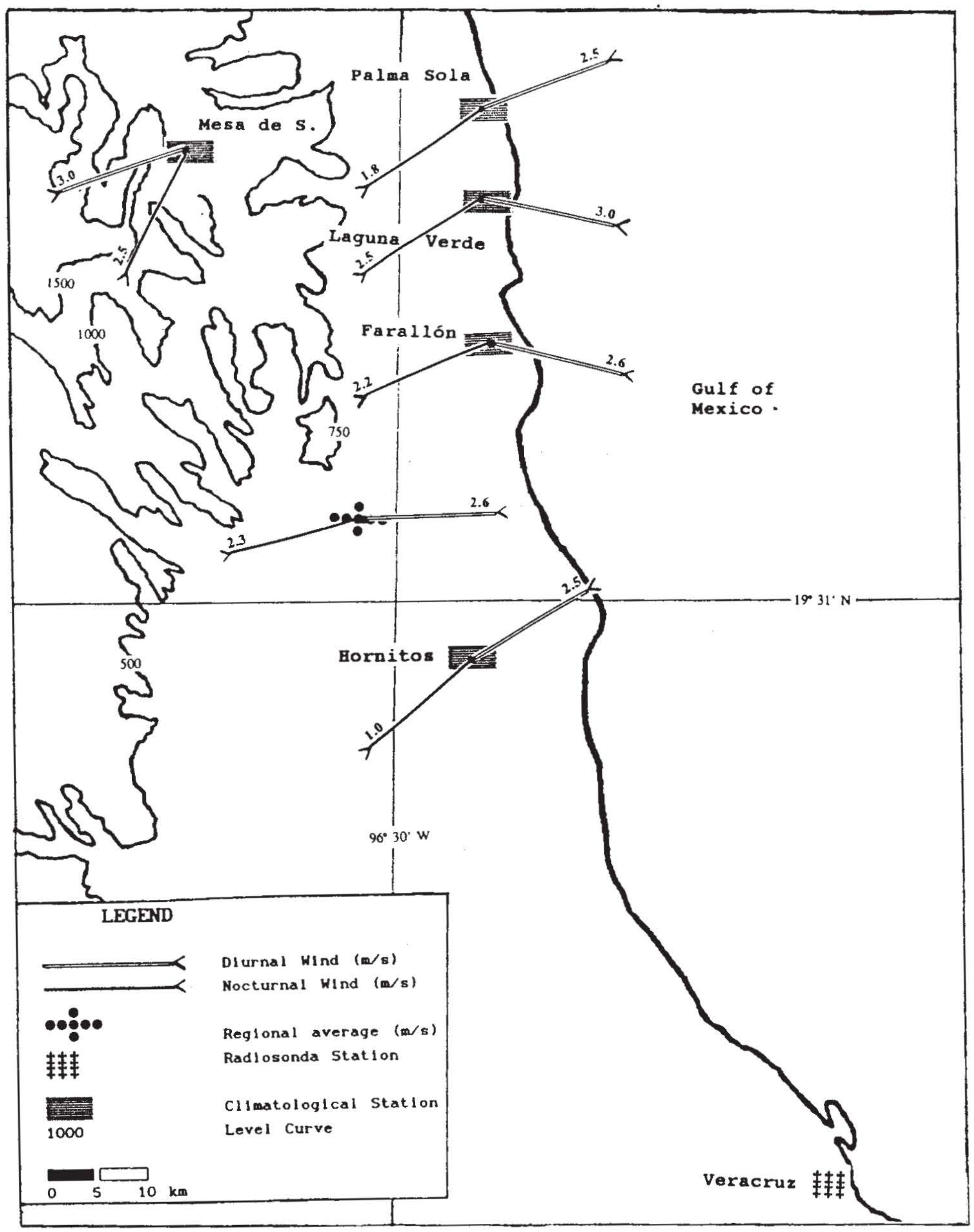

Fig. 2. Resultant winds (day and night) for October 1984.

substantially. The residual distribution supports multiple colinearity indicators (factors of inflation of variance) of the characteristic values of the matrix (X'X), but this does not mean that it is the cause of instability in the estimations (Ojeda, 1988).

An Andrew's sine transformation was implemented and the model was fitted to predict surface wind direction and speed. Checking results by both methods, it was found that wind coefficients in the 500 mb and synoptic situation were now lower for variables X1, X4 and X5.

These variables were eliminated and interactions were considered using Andrew's sine tranformation. We call this *Modified* Andrew's sine transformation. The results obtained by this method didn't change greatly with respect to those obtained by the two previous methods (see Table 2).

Andrew's sine transformation is used when the variance of errors is not constant. It is a weighted least-squares method. Weights are inversely proportional to the variance errors. With these robust methods the regression coefficients are estimated by minimizing the sum of square weighted errors. Then the coefficients are estimated basically with small observation deviation, which improves the fit. Modified Andrew's sines were used because we hoped to obtain a better fit (Mosteller and Tukey, 1977).

Table 1.

Correlation coefficient, variance and confidence interval for each station and day time, between wind speed and wind directions.

STATION	DAY TIME	CORRELACION COEFFICIENT	VARIANCE	95% CONFIDENCE INTERVAL
HORNITOS	Night Day	0.315 0.518	0.004 0.005	0.180-0.429 0.377-0.659
LAGUNA VERDE	Night Day	0.442 0.592	0.004 0.002	0.315-0.568 0.511-0.672
FARALLON	Night Day	0.302 0.515	0.002 0.004	0.181-0.420 0.388-0.642
PALMA SOLA	Night Day	0.115 0.335	0.005 0.007	0.098-0.311 0.168-0.501
MESA DE SOMBREROS	Night Day	0.386 0.406	0.003 0.006	0.273-0.499 0.259-0.553

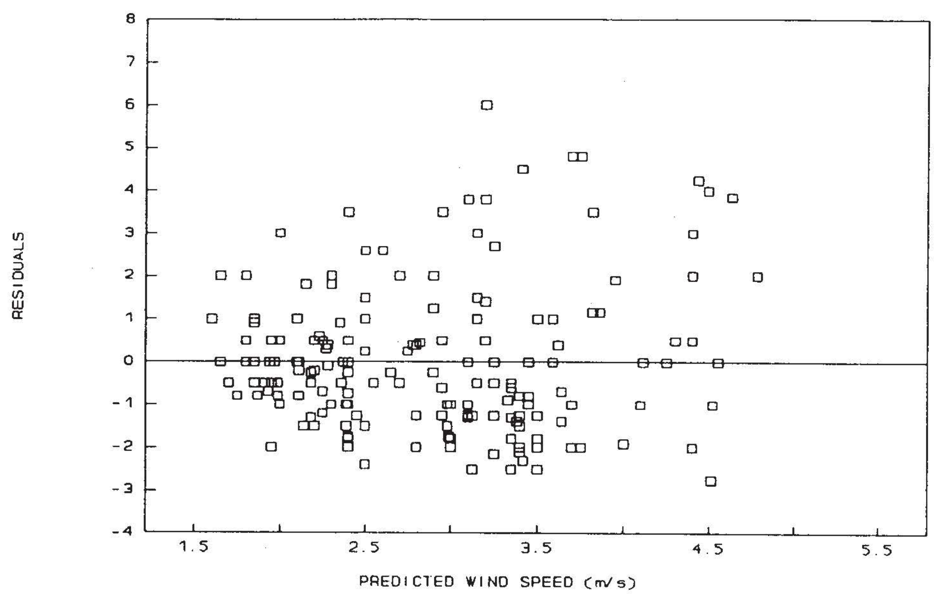

Fig. 3. Plot of residuals against predicted wind speeds (both in m/s).

CONCLUDING REMARKS

In Table 2, neither direction nor speed of surface wind keep a close relationship with the circulation in the middle troposphere (500 mb), as X_1 and X_4 coefficients are lower in all models. This is also true of the synoptic situation. Surface flux in the study area is caused by local factors: day or night time, cloudiness, atmospheric stability and horizontal air temperature variations.

These results differ from those of Cervantes (1987), who suggested the following variables by order of importance: time of day, wind speed at 850 mb, synoptic situation, intensity of thermal inversion, vertical stability and cloudiness.

The major modification with respect to Cervantes' results is the importance of the synoptic situation in the surface-850 mb relationship. It is suggested that this relationship is only valid for shallow systems but not for those extending from sea level to the middle troposphere. Possibly wind speeds at 850 mb are better reflected at the surface than at 500 mb.

For each model a contingency table was computed according to observed and predicted directions by multiples of $\pi/4$, about direction as indicated.

The correct predictions attain 63% for the three methods (Tables 3, 4 and 5, white squares). The incorrect cases (underlined squares) are more frequent for northerly directions than for directions with southerly components.

A more detailed analysis (Klaus, 1975; Jáuregui and Soto, 1975) suggests that weather in this zone is closely connected (mainly in summer) with the atmospheric circu-

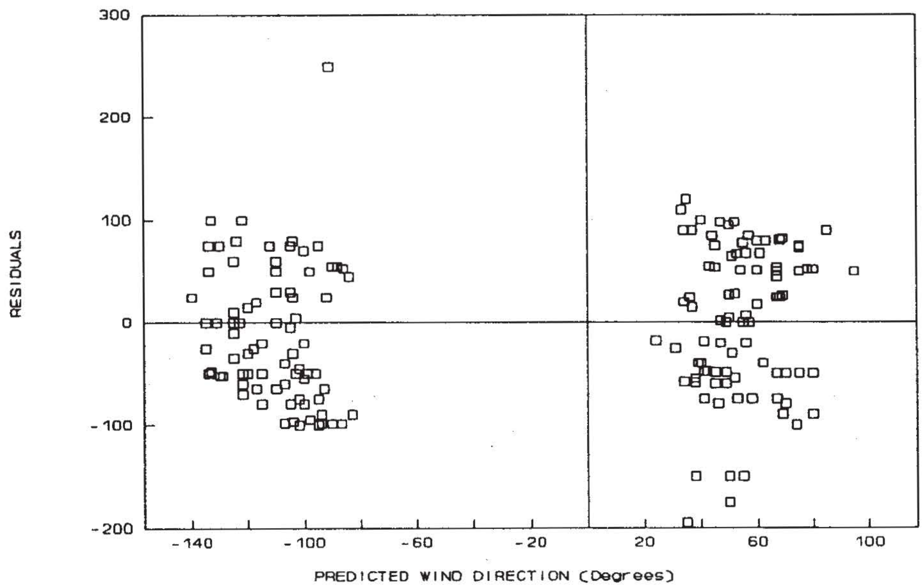

Fig. 4. Graphics of residuals against predicted wind directions (both in degrees).

Table 2

Surface wind direction (Y1) and speed (Y2) as multiple linear function of wind at 500 mb, calculated by three methods.

	Y1 Ldeast Square	Y1 Andrews Square	Y1 Modified Andrews Sine	Y2 Least Square	Y2 Andres Sine	Y2 Modified Andrews Sine
	*	*	*	*	*	*
X0	-102.10	-111.03	- 104.83	2.89	2.89	3.15
X1	- 0.03	0.02	0.00	-0.01	-0.002	0.00
X2	154.79	155.91	154.24	0.47	0.50	0.43
X3	5.55	7.09	6.86	-0.28	-0.23	-0.29
X4	- 0.01	- 0.06	0.00	0.04	0.02	0.00
X5	0.17	1.86	0.00	-0.01	-0.21	0.00
X6	- 28.49	- 29.50	- 29.64	0.07	-0.17	-0.28
X7	- 3.92	- 5.40	- 5.85	-0.08	0.05	0.03

* Regresion Coefficients
x0 = independent term; x1 = wind direction at 500 mb; x2 = time, x3 = atmospheric stability; x4 = wind speed at 500 mb; x5 = synoptic situation; x6 = cloudiness; x7 = temperature difference between land and coast.

Table 3.

Contingency table for ordinary least square method (100% = 233 cases).

OBSERVED DIRECTIONS

*	N	NE	E	SE	S	SW	W	NW	**	***
NE	10.7	7.3	4.3	11.2	0.1	0.0	1.3	3.4	22.3	16.0
E	4.7	0.0	1.7	3.4	0.9	0.0	0.0	0.0	5.1	5.6
SW	0.4	0.0	0.0	0.0	5.6	10.7	3.0	4.3	19.3	4.7
W	2.6	0.0	0.0	0.0	6.4	9.4	1.3	6.0	16.7	9.0
TOT	18.4	7.3	6.0	14.6	14.2	20.2	5.6	13.7	63.4	35.3

*Predicted Directions. ** Almost Correct Predictions.
*** Total Incorrect Predictions.

Table 4.

Contingency table for Andrews Sine method (100% = 233 cases).

OBSERVED DIRECTIONS

*	N	NE	E	SE	S	SW	W	NW	**	***
NE	10.3	6.9	4.7	11.2	1.3	0.0	1.3	3.4	21.9	17.2
E	5.1	0.4	1.3	3.4	0.8	0.0	0.0	0.0	5.1	5.9
SW	0.8	0.0	0.0	6.9	6.9	12.4	3.0	6.0	22.3	6.8
W	2.1	0.0	0.0	5.1	5.1	7.7	1.3	4.3	13.3	7.2
TOT	18.4	7.3	6.0	14.2	14.2	20.2	5.6	13.7	62.6	37.1

*Predicted Directions. ** Almost Correct Predictions.
*** Total Incorrect Predictions.

Table 5.

Contingency table for modified Andrews Sine method (100% = 233 cases).

OBSERVED DIRECTIONS

*	N	NE	E	SE	S	SW	W	NW	**	***
NE	11.2	7.3	5.1	11.6	1.3	0.0	1.3	3.4	23.6	17.6
E	4.3	0.0	0.8	3.0	0.8	0.0	0.0	0.0	1.1	5.1
SW	0.8	0.0	0.0	0.0	7.3	12.9	3.4	6.9	23.6	6.8
W	2.1	0.0	0.0	0.0	4.7	7.3	0.8	3.4	11.5	6.8
TOT	18.4	7.3	6.0	14.6	14.2	20.2	5.6	13.7	59.8	37.2

*Predicted Directions. ** Almost Correct Predictions.
*** Total Incorrect Predictiones.

lation in the Gulf of Tehuantepec on the Pacific side (92° to 97°W, 14° to 16°N), rather than to the Gulf of Mexico. A new attempt including this element might be worthwhile.

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