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The surface wind direction as a function of the wind at 850 mb in Laguna Verde zone, Veracruz, Mexico

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RESUMEN

Mediante la aplicación de un método de regresión lineal múltiple, fue posible relacionar la circulación superficial atmosférica con la circulación a 850 mb, como una función de la hora del día, la situación sinóptica presente, la magnitud del viento a 850 mb, la estabilidad atmosférica, las inversiones térmicas por abajo de 850 mb y la nubosidad. Los coeficientes de correlación obtenidos fueron altos, pero no así la significancia.

ABSTRACT

By applying a method of linear regression, it was possible to relate the surface wind shift with respect to the wind direction at 850 mb as function of time of day, actual synoptic situation, wind speed at 850 mb, atmospheric stability, existence of thermal inversions up to 850 mb, and cloudiness. The correlation coefficients obtained in the computations were high, but the sample sizes were small.

1. Introduction

There are several antecedents about the establishment of relationships between wind circulations at a given altitude and surface. Schreffler (1982); Kau *et al.* (1982) and Ryan (1977), analysed separatedly magnitudes and directions under the hypothesis that the surface wind is the resultant of circulations superimposed at different scales.

Following a similar criterion, Johnson *et al.* (1986) studied the surface mean wind direction dependence on the gradient wind in a mountainous area of approximately 600 km^2 in Australia. The method consisted of implementing a regression equation for each direction (there were eight), where regional direction consisted of the spatial mean of 17 surface stations and was related to the gradient wind at 850 mb, obtained from the radiosondes launched in Camberra, time of day, season and gradient wind speed.

In Mexico there has been little research about the dependence between the altitude and surface wind. In this paper, quantitative relationships between the directions of the surface and 850 mb wind are presented. The direction of the surface wind is defined as an average of angular variables (Mardia, 1972), in space as well as in time, for the Laguna Verde area, Veracruz (Mexico), and the 850 mb wind direction is computed from the radiosondes launched in the Veracruz Port (Fig. 1).

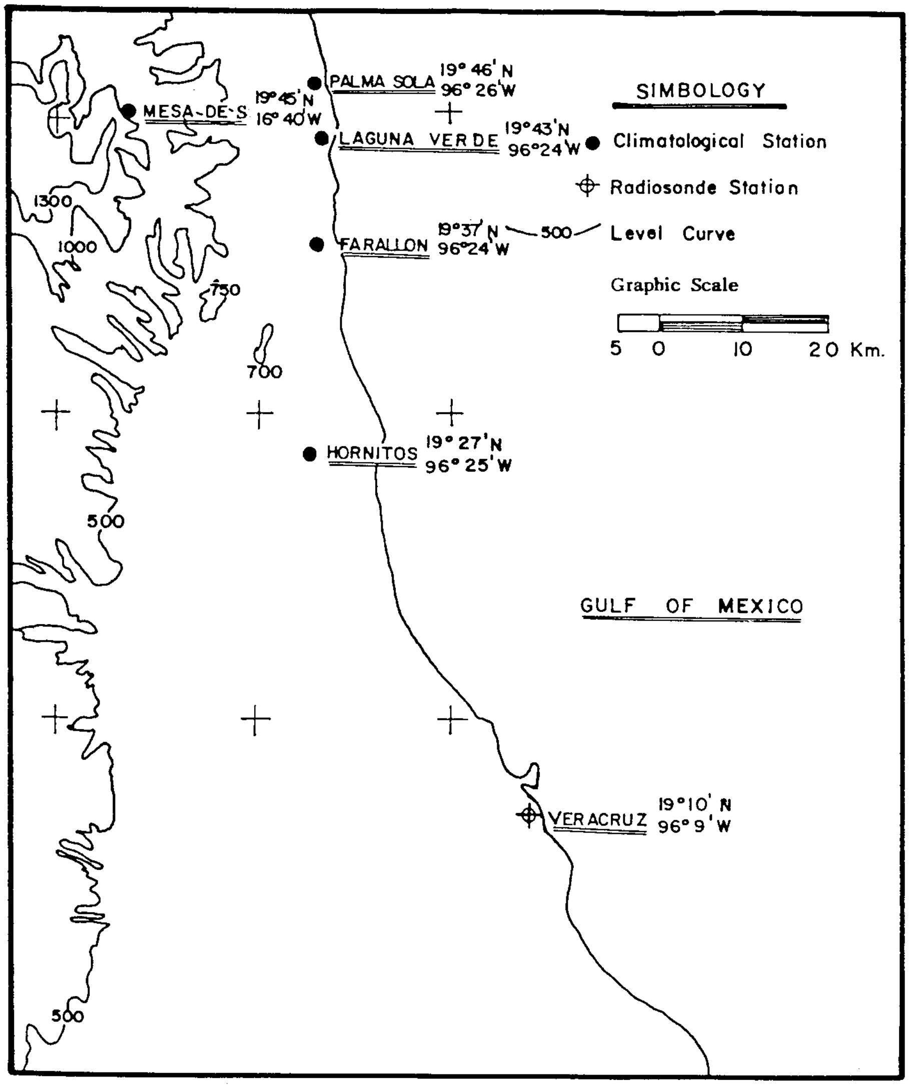

Fig. 1. Radiosonde and climatological stations.

2. Angular variables statistics

According to Mardia (1972), the mean angle X_o corresponding to the sample $[\theta_1, \theta_2, \ldots, \theta_n]$ is satisfied by

$$C = R \cos X_o \tag{1}$$

$$S = R \sin Xo \tag{2}$$

where

$$C = (1/n) \sum_{n}^{i=1} \cos \theta_i;$$

$$S = (1/n) \sum_{n}^{i=1} \sin \theta_i;$$

$$R = \sqrt{C^2 + S^2}$$

This is valid if the magnitudes of the vectors V_i, having the directions θ_i, are not very dispersed. If they are, the mean direction X_o is (Cervantes, 1987):

$$X_0 = \text{arc tang } S_w/C_w \tag{3}$$

where

$$S_w = (1/n) \sum_{i=1}^{n} V_i \sin \theta_i \tag{4}$$

and

$$C_w = (1/n) \sum_{i=1}^{n} V_i \cos \theta_i \tag{5}$$

The directions or angles measured in this way, meet the circular normal distribution, or Von Mises function (Gumbel *et al.*, 1953) if they are distributed normally around the mean value. In that case it is possible to apply the maximum probability postulate (f' means the first derivative):

$$\sum_{i=1}^{n} \frac{f'(\theta_i - X_o)}{f(\theta_i - X_o)} = 0 \tag{6}$$

that leads to the distribution function:

$$f(\theta) = [1/[2\pi I_o(h)]] \text{ exp } h \cos (\theta_i - X_o) \tag{7}$$

where I_o (h) is the modified Bessel function of the first class and zero order. h is the Kurtosis of $f(\theta)$.

Gould (1969) describes one type of linear regression for angular variables, similar to the one used in this paper, which implies that the errors are normally distributed. That is, one group of observations $\theta_1, \theta_2, \ldots, \theta_n$ corresponding to k angular variables $Z_i (i = 1, 2, \ldots, k$; in our case $k = 16)$, will be distributed with a Von Mises function:

$$g(Z, Q, h) = [1/(2\pi I_o(h))] \text{ exp } h \cos (Z - Q) \tag{8}$$

where each distribution presents a certain Kurtosis h, and its mean is $Q = B_o + B_i t_i$; the parameters B_o and B_i are unknown, while t is a vector of known variables (The independent variables).

In a similar way to the linear data regression, B_o and B_i are estimated using a maximum probability technique, that is, if L is the logarithmic probability function

$$L = C + h \cos (Z - Q) \tag{9}$$

then B_o and B_i are solutions of the equations:

$$\frac{\partial L(B_o,\ B_i)}{\partial B_o} = 0 \ \text{ or } \ \sin\ (Z - Q) = 0 \tag{10}$$

and

$$\frac{\partial L(B_o,\ B_i)}{\partial B_i} = 0 \ \text{ or } \ \sin(Z - Q) = 0 \tag{11}$$

for $i = 1, 2, \ldots, m$ if B has m elements. Such equation can be solved by an iterative method.

3. Information processing

The information used was one year (1984) of wind hourly data registered in five climatic stations distributed in the study area (Fig. 1); data from radiosondes launched in the Veracruz Port at 6 and 18 hours local time, and the surface synoptic charts of those hours.

It was considered that the radiosonde data at 6 hours local time was representative of the nocturnal period (3 to 8 hours), and that the radiosonde data at 18 hours representative of the diurnal period (15 to 20 hours).

With the methods described in section 2, the mean direction in each period and the mean direction for all stations were calculated in order to determine an areal mean direction for each period.

The independent variables considered in this paper were: the period of days (P), the synoptic situation (SS), the wind speed at 850 mb (VV), the atmospheric stability (E), the existence of temperature inversions (TI) and cloudiness (N). The parameters categorization is shown in Table 1.

Table 1. Independent variables categorization

	Period, P =	Synoptic Situation, SS=	Wind Speed 850 mb, VV=	Vertical stability, E =	Temperature inversions* below 850 mb, TI =	** Cloudiness, N =
- 4					Two inversions either type (b) or type C	
- 3					Two inversions, one type (a) and the other either type (b) or (c)	
- 2				Absolutely stable	One inversion type (b) or type (c)	
- 1	3-8 Hrs.			Stable	One inversion type (a)	
0		Neutral point		Indifferent	Without inversion	0 to 2 octas
1	15-20 Hrs.	Low	5 to 15 m/s	Conditionally stable		3 to 4 octas
2		East or high	15 to 25 m/s	Absolutely unstable		5 to 6 octas
3		Front	more than 25 m/s			7 to 8 octas

* INVERSIONS TYPE: (a) Weak $0°C < \Delta T/\Delta Z < 1°C$
(b) Slight $1°C \leq \Delta T/\Delta Z < 2°C$
(c) Strong $\Delta T/\Delta Z \geq 2°C$

**Mean and low clouds

Three types of temperature inversions or their combinations were found below 850 mb:

A) WEAK: $0^oC < \Delta T/\Delta z \leq 1^oC$

B) SLIGHT: $1^oC < \Delta T/\Delta z \leq 2^oC$

C) STRONG:$\Delta T/\Delta z > 2^oC$

Since the theory supposes a normal distribution of the errors, the arc Ψ between the mean surface wind direction and at 850 mb, was used as a dependent variable. It was calculated in radians and it was considered positive in the counterclockwise direction. The variables categorized in the Table 1 were used as independent variables. The coefficients of the following equation were evaluated for each one of the twelve directions considered at 850 mb:

$$W = B_o + B_1 P + B_2 SS + B_3 VV + B_4 E + B_5 TI + B_6 N \tag{12}$$

The coefficients of linear regression (B), the coefficients of correlation (r) and the standard errors of regression (ESR) given in radians, are shown in Table 2.

Table 2. Regression coefficients (B), multiple linear correlation coefficients (r) and regression standard errors (ESR) in radians, for the equation (12). There were not enough cases to determine the coefficients for the SSW, SW, WSW and W directions.

850 mb wind directions	B_o	B_1	B_2	B_3	B_4	B_5	B_6	r	ESR	Cases
N	-0.18	0.80	-0.02	0.04	0.16	0.14	0.0	0.75	0.78	29
NNE	0.27	1.04	0.58	-1.42	-0.20	0.24	-0.06	0.96	0.49	15
NE	-1.14	1.31	0.45	0.23	0.37	0.08	-0.33	0.83	1.15	48
ENE	3.64	-1.91	0.27	-1.39	-0.33	0.51	-0.29	0.93	0.80	22
E	2.25	-0.72	0.66	0.52	-0.32	1.05	-0.62	0.75	1.16	28
ESE	0.70	-1.70	-0.04	-0.55	0.11	-0.04	0.10	0.97	0.37	37
SE	0.13	-1.18	0.07	-0.44	0.10	-0.26	0.01	0.85	0.68	86
SSE	-0.66	-0.57	0.02	0.51	-0.06	-0.14	0.29	0.79	0.76	19
S	-0.79	-2.05	1.93	-2.01	-0.06	-0.43	-0.28	0.99	0.27	15
WNW	1.83	1.00	-0.33	-0.35	0.01	0.23	-0.19	0.81	0.84	20
NW	-2.06	0.25	0.17	0.32	0.01	0.03	0.51	0.67	0.95	49
NNW	0.47	0.89	-0.08	-0.34	0.02	0.10	0.0	0.80	0.74	31

It must be clear that the values of r in Table 2 are a convenient measure of the goodness of the model, since the independent variables are not correlated (Table 3).

Table 3. Table of crossed correlations between the independent variables of the equation (12). The calculation cover 399 analysed cases.

	P	SS	VV	E	TI	N
P	1	0.124	-0.003	-0.002	0.337	0.013
SS	0.124	1	0.060	-0.070	0.224	0.003
VV	-0.003	0.060	1	0.014	0.055	0.096
E	-0.002	-0.070	0.014	1	-0.038	0.083
TI	0.337	0.224	0.055	-0.038	1	0.327
N	0.013	0.003	0.096	0.083	0.327	1

4. Results and conclusions

This paper presents a trustworthy relation between the wind directions at 850 mb and surface for the region of study. The goodness of equation (12) is high, as the values of r in Table 2 are shown.

Our results improve those obtained by Johnson *et al.* (1986) for the Camberra region. The principal reason is because our study zone has a less steep orography and because the local wind regime (Sea/Land breeze) is very persistent.

Comparing the coefficients of the simple correlation between Ψ and each one of the predictors (Table 4), it is clear that the dominant element is the time of day. Which means that is the local circulation who determines the magnitude.

Table 4. Coefficients of partial correlation for each one of the terms B_iX_i of the equation (12) and each of the directions of Table 2.

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	WNW	NW	NNW
B_1P	0.480	0.2381	0.2701	0.7999	0.0177	0.2740	0.3355	0.0719	0.8083	0.1701	0.1297	0.4081
B_2SS	0.0006	0.1704	0.0053	0.0997	0.0659	0.0026	0.0298	0.0110	0.5942	0.0196	0.0002	0.0246
B_3VV	0.0013	0.0948	0.0066	0.1395	0.0033	0.0018	0.0059	0.0159	0.2589	0.0129	0.0656	0.0093
B_4E	0.0668	0.0092	0.0061	0.2100	0.1921	0.0139	0.0279	0.0226	0.0731	0.0240	0.0002	0.0060
B_5TI	0.0324	0.1456	0.0	0.2763	0.1788	0.0925	0.0584	0.0376	0.0504	0.0293	0.0056	0.0135
B_6N	0.0000	0.0793	0.0682	0.1781	0.0523	0.036	0.0082	0.1047	0.0273	0.0604	0.0635	0.0702

The importance of the other predictors is different for each direction at 850 mb. However, it is clear that the thermal inversions together to a vertical atmospheric stability (TI and E) determine, in a great extent, the importance of the relation between the circulation at the surface and at 850 mb, principally when this one has a strong component of E.

It can be concluded that Table 2 and equation (12) are very useful for the prediction of the local circulation, if the terms of the equation (12) can be anticipated.

However, the relatively high values of (ESR) indicate the necessity of making some improvements, as the verification of the representativeness of the named "superficial mean direction", and a better categorization of the independent variables, especially because the authors search to stablish the dependence of the surface wind direction on the 500 mb wind.

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REFERENCES

Cervantes, J., 1987. Relationship between the wind directions at 850 mb and the surface wind direction in Laguna Verde zone, Veracruz. (In Spanish). Bachelor Thesis, pp. 87, Facultad de Física Universidad Veracruzana. (Available copies).

Gould, A. L., 1969. A regression technique for angular variates. *Biometrics,* **25,** 683-700.

Gumbel, E. J., J. A. A Greenwood and D. Durand, 1953. The circular normal distributions: theory and tables. *J. Am. Statist. Ass.* **48,** 131-152.

Johnson, M. E., J. D. Kalma and D. Pederson, 1986. A study of the dependence of surfacewind direction on the gradient wind. *Month. Wea. Rev.*, **114,** 257-269.

Kau, W. S., H. N. Lee and S. K. Kao, 1982. A statistical model for wind prediction at a mountain and valley station near Anderson Creek, California. *J. of Appl. Meteor.*, **21,** 18-21.

Mardia, K. V., 1972. Statistics of directional data. Ac. Press. 357 pp.

Ryan, B. C., 1977. A mathematical model for diagnosis and prediction of surface winds in mountainous terrain. *J. Appl. Meteor.,* **16,** 571-584.

Shreffler, J. H., 1982. Intercomparisons of upper air and surface winds in an urban region. *Boundary Layer Meteorology,* **24,** 345-356.