Correlation between northers of Gulf of Mexico and frosts at Las Vigas, Veracruz, Mexico

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RESUMEN

En este estudio se da a conocer la correlación que existe entre los nortes que azotan las costas del Golfo de México y las heladas que se presentan en Las Vigas, Veracruz, con base en el análisis de los registros climatológicos de ese lugar, del periodo 1959-1987.

Se clasifican las heladas por su origen y por su tipo; resultando ser, por su origen, las radiativas, y por su tipo, las heladas blancas, las más frecuentes en la región. El análisis de correlación entre los nortes y las heladas blancas arrojó un coeficiente de correlación $r = 0.480$, el cual es significativo al 1%.

ABSTRACT

This paper discusses the correlation between northers, which lash the coasts of the Gulf of Mexico, and frosts which occur in Las Vigas, Veracruz, based on the climatological records of this place from 1959-1987.

The frosts are classified according to their origin and type. The first being radiative and the second ones white frosts, which are more frequent in this region.

From the correlation analysis between the northers and the white frost, it was found a correlation coefficient $r = 0.480$, which is significative at 1%.

1. Introduction

Due to big losses caused by the frosts in the agricultural region called Valley of Perote, Ver., the University of Veracruz, through the Center of Applied Meteorology of the Physics School, decided to carry out this study. It would be of interest for everyone involved with the agricultural sector, mainly the farmers of this region.

The area of study is located in the municipality of Las Vigas, Ver., México, which is part of the Valley of Perote. For this study the climatological data were collected from the meteorological station, "Las Vigas", located at 19°38' north latitude and 97°05' west longitude. It has an elevation of 2481 meters above sea level (Fig. 1).

2. Geographical description of the Valley of Perote

The Valley of Perote is located between 19°20' and 19°50' north latitude and 97°05' and 97°40' west longitude. It has a mean elevation of 2,440 meters above sea level and its extension is approximately 100,000 hectares (Fig. 1). The main crops of the region of Valley of Perote are shown in Table I.
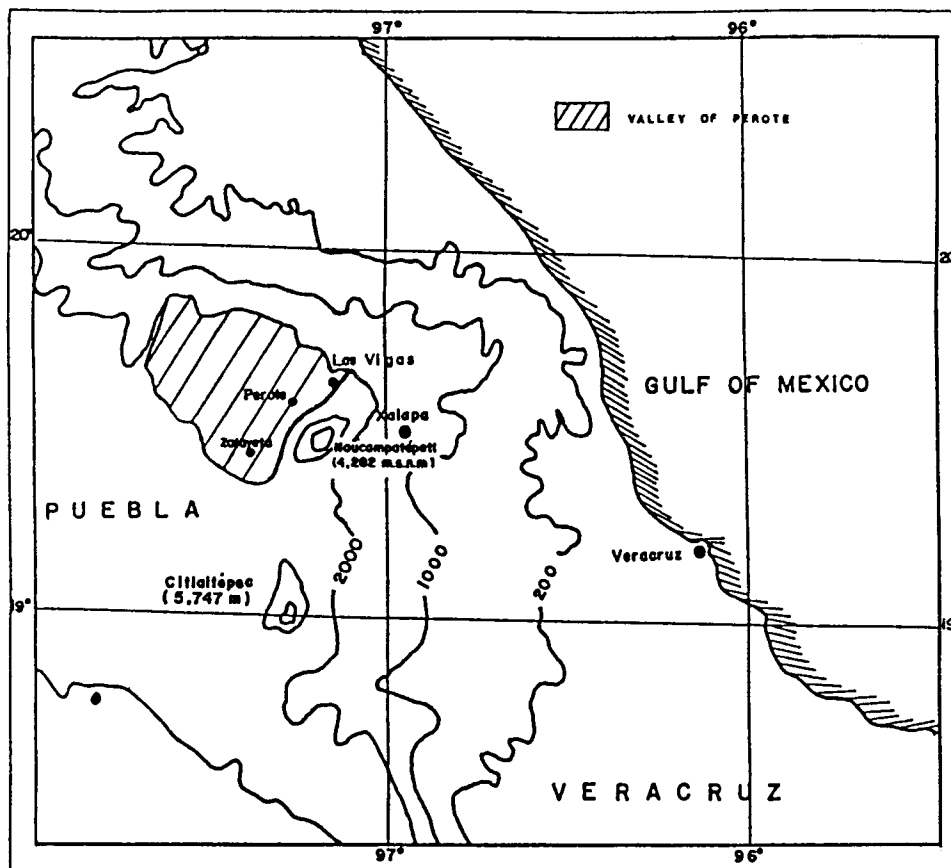

Fig. 1. Location of the study area.

Table I. Main crops grown in the Valley of Perote during 1980 (Source: SARH).

Crops	Surface (hectares)
Corn	18,560
Potato	5,213
Wheat	4,596
Broad bean	2,533
Pea	1,104
Barley	276
Bean	64
Total	32,346

3. Climate of the region of study and criterion to determine situations of norther

According to Kopen's classification (García, 1986) the climate at Las Vigas, Ver., is subhumid moderate with rains in summer. This is due to the fact that the precipitation of the wettest month during the hottest season of the year is 10 times more than that of the driest month. It has an average annual precipitation of 1050 mm and an average annual temperature of 11.7°C. The Valley of Perote has two more climates: a dry arid and dry semiarid with rains in summer. In dry arid, average annual precipitation is of 255 mm and at dry semiarid, the average annual precipitation is of 421 mm, the average annual temperature is of 13.6°C and 12.6°C, respectively.

Mosiño *e⁻ al.* (1974) said that northers from the Gulf of Mexico are boreal winds which blow violently during winter for two or three days continuously over the coastal plain of the Gulf. They are associated with a modified polar continental air mass which in form of cold and dense ridge penetrates the Gulf on the north part behind a diffuse cold front. This front separates the warm tropical maritime air from modified polar air and constitutes a true invasion of cold or moderate air from northern latitudes toward the intertropical zone, affecting the states of Tamaulipas, Veracruz, Tabasco, Campeche and Yucatan (Fig. 6).

4. Origin of the frosts at Las Vigas, Veracruz

To determine the origin of the frosts at Las Vigas, Ver., Mexico, we used the records of presence of frosts, velocity and direction of prevailing winds, cloud cover reported by the climatological station at Las Vigas, Ver., as well as the northers reported during the period 1959-1987 by the Observatory of the Forecast Center of the Gulf of Mexico (C. P. G. M., 1987).
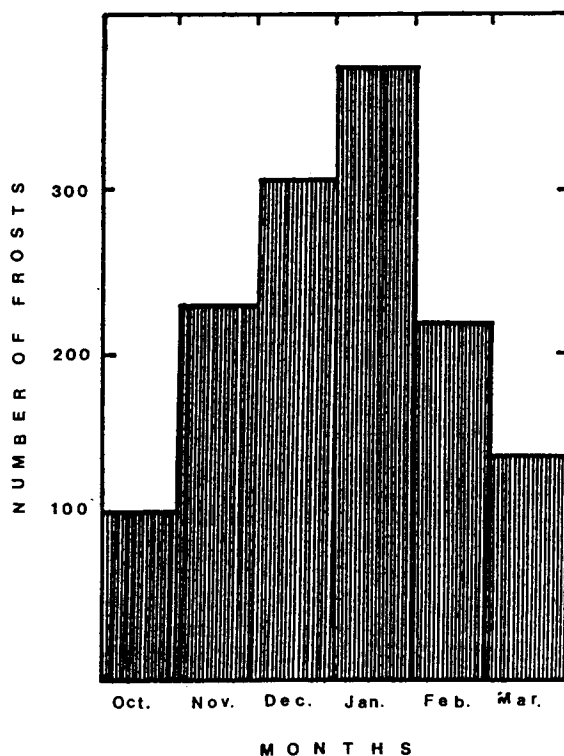

Fig. 2. Temporal distribution of the frosts in Las Vigas, Veracruz, period 1959-1987.

First, the days with frost were found. With these data the climatological information of the zone of study was reviewed, as well as of the Veracruz Port, to see if the frost were related to the presence of northers in the Gulf of Mexico. The climatological analysis shows that the frosts observed at Las Vigas, Ver. are according to their origin, radiative and advective. The first ones occur generally after the northers with clear skies. The second ones occur during the presence of northers; in other words, with the arrival of a cold air mass which cause the temperature to decrease. These frosts occur with or without cloudy skies.

These frosts can be of two types, the white frost and the black frost. The white frost is the most frequent at Las Vigas, and is reported with the presence of hoarfrost. The least frequent is the black frost, which occurs with the decrease of temperature below 0°C and there is not hoarfrost, as the dew point temperature is not reached. This type of frost is more harmful to the agriculture at Las Vigas and the Valley of Perote, Ver., and it occurs one or two days after the maximum wind at Port of Veracruz (31 to 65 m/s) is recorded. Figure 2 shows the temporal distribution for all frosts observed at Las Vigas during the period 1959-1987.

5. Correlation between the northers and the frosts

Correlation analysis is a statistical tool which has been used by some authors (Parthasarathy and Sontakke, 1988; Mosiño and Morales, 1988) to determine the degree of relation existing between a synoptic situation and certain climatological variable. In this case, we are trying to find a relationship between annual frequency of northers of the Gulf of Mexico and frosts of Las Vigas, Veracruz.

On performing the correlation analysis between northers (589) and white frosts (1276) that were observed during the period 1959-1987, it was considered as white frost when the shelter temperature decreased below 0°C and hoarfrost was registered. We used a computation statistical pack (Stat Pack 3.1) and a personal computer, with this help 4 functions (linear, exponential, curve power and logarithmic) were fitted, and the one of best fit was selected in each case. We found a coefficient of correlation $r = 0.480$, which is significative at 1% (Snedecor and Cochran, 1967; Little and Hills, 1976). The determination coefficient ($r^2 = 0.231$) indicates that 23% of the variance of frost frequency can be explained by frequency of northers (Fig. 3).
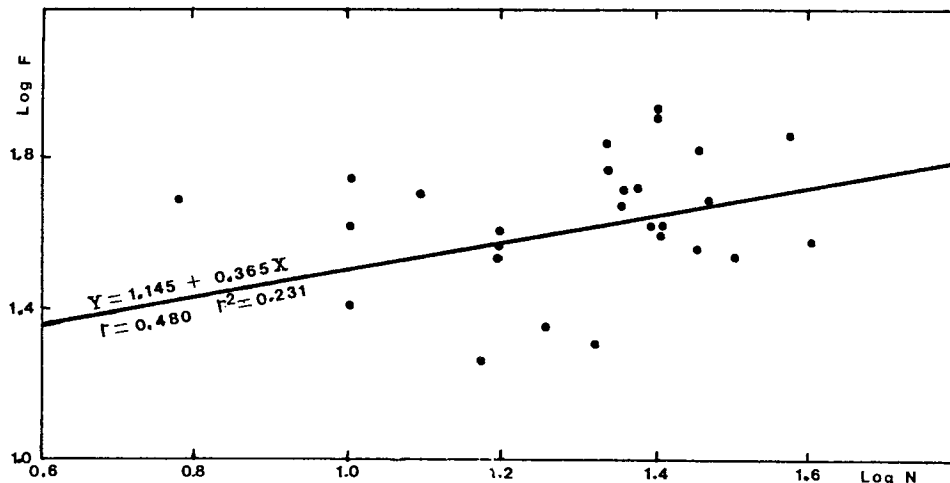

Fig. 3. Regression analysis between year number of northers in the Gulf of Mexico and white frosts registered at Las Vigas, period 1959-1987. (F) Number of white frosts. (N) Number of northers. (Y) log F and (X) log N.
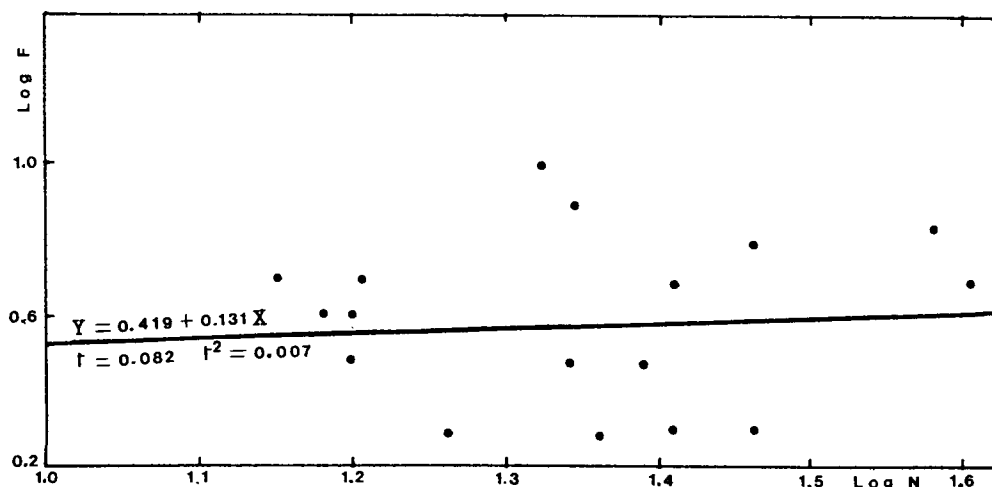
Fig. 4. Regression analysis between year number of northers in the Gulf of Mexico and black frosts registered in las Vigas, Veracruz, period 1959-1987. (F) Number of black frosts. (N) Number of northers. (Y) log F and (X) log N.
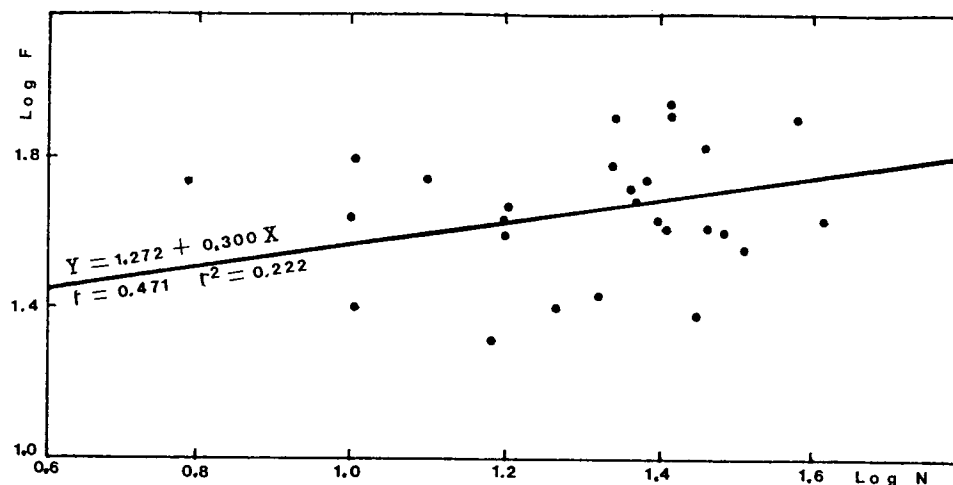

Fig. 5. Regression analysis between number of northers per year in the Gulf of Mexico and frosts (white plus black) registered in Las Vigas, Veracruz, Period 1959-1987. (F) Number of frosts (white plus black). (N) Number of northers. (Y) log F and (X) log N.

Figure 4 shows the correlation between northers and black frosts (99). It was considered as black frost when the shelter temperature decreased below $0°C$ and no hoarfrost was registered. The correlation coefficient obtained was only 0.082, which is not significative at the 5% level.

Figure 5 shows that correlation between northers and the total number of frosts (white plus black frosts) is $r = 0.471$, which is significative at 1%, and the determination coefficient $r^2 = 0.222$ indicates that 22% of variance of frost frequency at Las Vigas, Ver., can be explained by frequency of northers.

6. Synoptic situation at Las Vigas with the presence of an intense norther at the Port of Veracruz

On March 5th 1989, a norther of hurricane proportions was reported at the Port of Veracruz, with gusts up to 33 m/s (118.8 km/hr). As a result the port was closed to navigation and the consequences were felt at Las Vigas, Ver. The synoptic situation was the following:

The surface map of March 4th, at 18:00 local time shows the elongation of an anticyclonic system (ridge) located at the northern side of USA. With a pressure of 1041 mb in its center; this ridge begins to affect the regions of northern Mexico. On the east side, a frontal system is located from Tamaulipas to the Great Lakes region.

The anticyclonic system produces moderate to strong winds from 10 to 15 m/s. At Monterrey and Brownsville, winds from 7.5 to 10 m/s are observed, the rest of the littoral remains without change.

By March 5th, 06:00 local time (Fig. 6), the ridge intensifies and affects most of the littoral of the Gulf of Mexico. The frontal system extends from the middle part of Veracruz to a low pressure system on the southeast of USA. As it can be observed, the flow of polar continental air produces northern winds in most of the littoral. However, over the southeastern side of the country, south, southeast and southwest winds prevail.
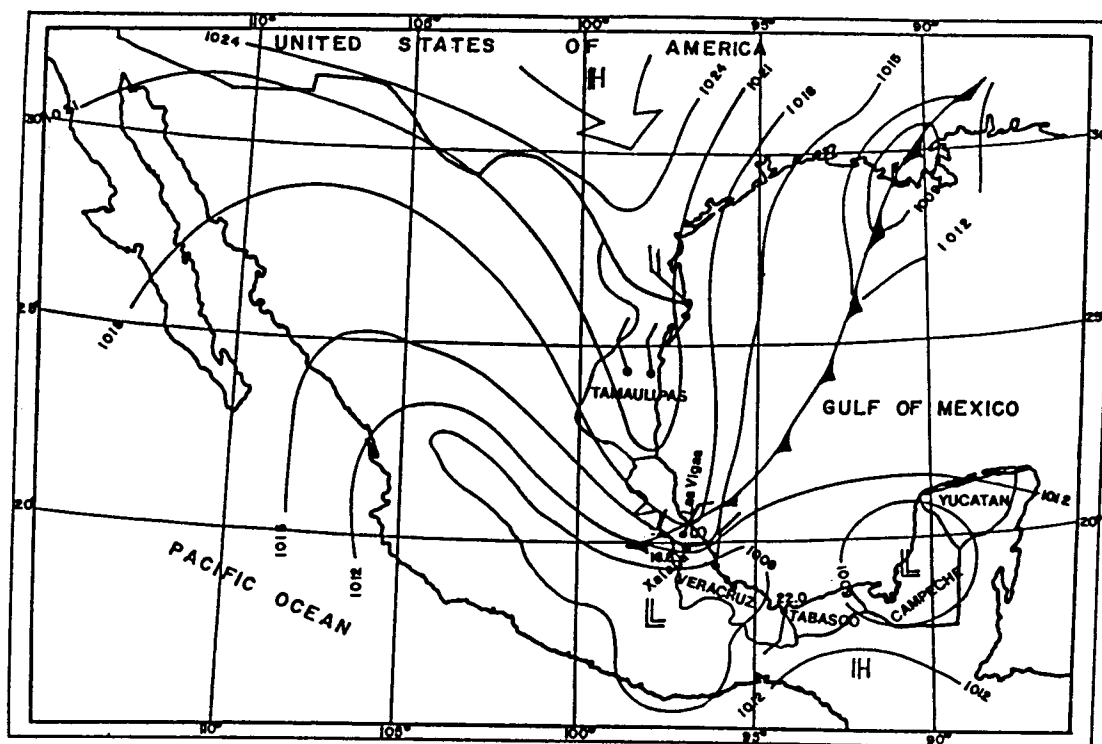

Fig. 6. Synoptic situation of March 5th, 1989, at 6:00 local time.

Likewise, it is observed that, although the ridge is located near Xalapa, Ver., the temperature there at 6:00 local time is relatively high (16.8°C). This indicates that the polar mass will affect the area in the next 12 or 15 hours (Fig. 6).

In the afternoon surface analysis (Fig. 7), the ridge covers most of eastern Mexico. The frontal system, remains almost parallel to the littoral, vanishing on southeastern USA.

The winds have already decreased in the state of Tamaulipas and northern Veracruz. However, at the stations of Veracruz, Coatzacoalcos and Salina Cruz, a norther blows, with speeds from moderate to strong (Fig. 7). This verifies the damming effect mentioned by Mosiño and García (1974) and Fitzjarrald (1984).
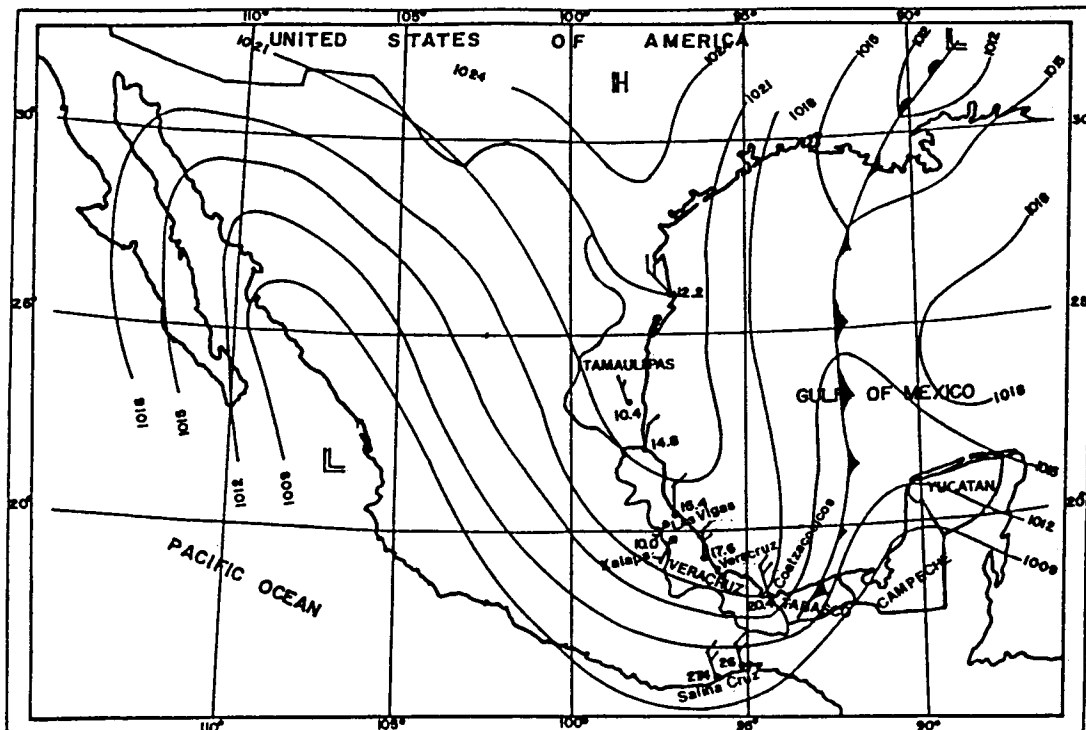

Fig. 7. Synoptic situation of March 5th, 1989, at 18:00 local time.

It should be mentioned that even though the northern winds have decreased on most of the littoral of the Gulf, the temperature begins to decrease, so that a temperature of 10°C is registered at Xalapa, Ver. Observe that the frost begins to be generated. At 18:00 local time the wind has a weak component from the south-southwest. This may indicate that even though a norther exists the advection of maritime tropical air persists aloft.

The analysis of March 6th, at 06:00 local time (Fig. 8) shows that the ridge has decreased a little bit; however, the temperatures are low (1.1°C) at Brownsville and (-1.0°C) at Las Vigas. As it is observed, it takes from 12 to 18 hrs to cause a decrease of temperature in anyone place on the pressure line. This indicates that the passage of the ridge or norther does not generates a decrease of temperature at once.
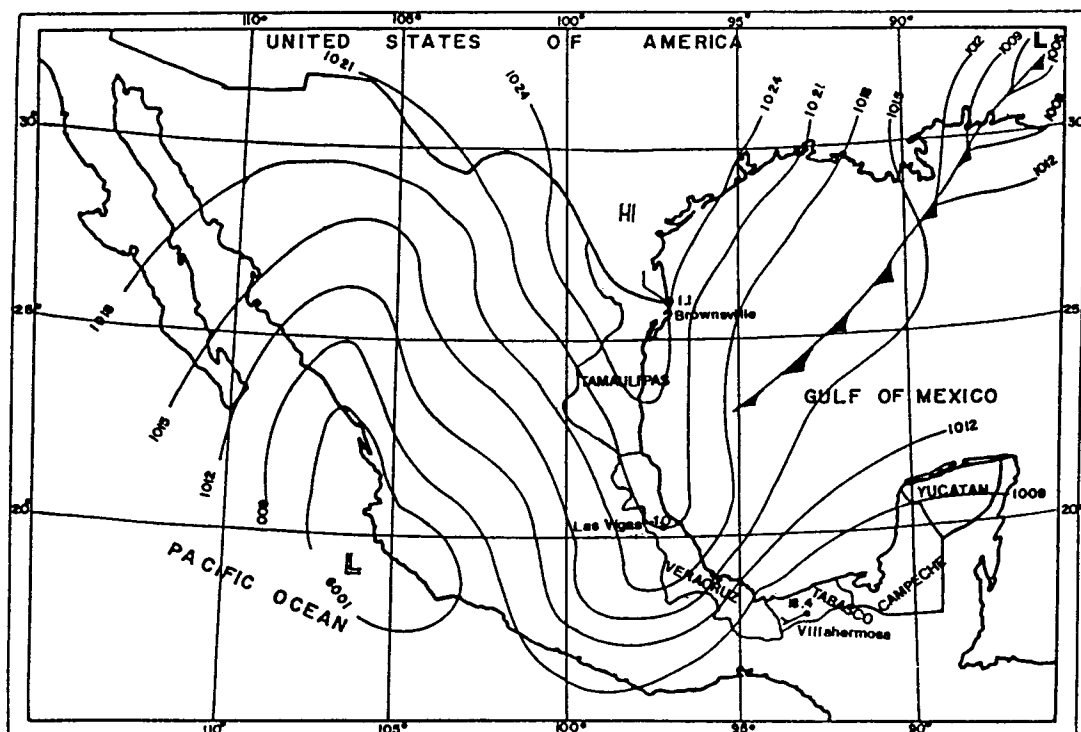
Fig. 8. Synoptic situation of March 6th, 1989, at 6:00 local time.

The climatological data at the station Las Vigas, Veracruz, during the first 12 days of March 1989, are shown in table II.

Table II. Climatological data of Las Vigas, vercruz, during the first 12 days of March 1989.

Day	Ambient Temperature (°C)	Maximum Temperature (°C)	Minimum Temperature (°C)	Direction velocity of wind	Cloud cover	Frosts occurrence	Snow occurrence
1	9.0		7.0	NE	○	0	0
2	6.0	20.0	4.0	SW	○	0	0
3	7.0	21.0	5.0	NE	○	0	0
4	5.0	17.0	3.0	NE	●	0	0
5	2.0	12.0	1.0	NE	●	0	0
6	0.0	10.0	-1.0	SW	●	BF	0
7	1.0	12.0	-3.0	SW	●	0	0
8	-5.0	5.0	-7.0	NE	◑	0	snowfall
9	-3.0	7.0	-5.0	CA	◑	BF	0
10	0.0	10.0	-2.0	NE	○	WF	0
11	1.0	14.0	-3.0	CA	○	WF	0
12	3.0	17.0	1.0	E	○	0	0

BF - Black frost   WF - White frost

It can be observed that an intense norther (32 m/s) registered at the Port of Veracruz originated frosts two days after its occurrence in Las Vigas, Veracruz, Mexico. Table III shows the classification of northers according to their intensity.

Table III. Classification of northers according to their intensity

Norther	Intensity (m/s)
Moderate to fresh	4.1 - 12.0
Fresh to strong	12.1 - 18.0
Strong to violent	18.1 - 29.0
Hurricane wind	> 19.0

7. Conclusion and general remarks

From the climatological analysis performed for each frost observed at Las Vigas, Ver., it was found that its origin is mainly of radiative type (75% approximately) and 25% of advective type. White frosts and black frosts are included, being the first ones the most frequent (93% approx.) and the second ones the least frequent (7% approx.). However, the last ones cause more damage to the crops of the region (Pereyra and Zitacuaro, 1988; García and Valdez, 1988).

In Figure 2, it can be observed that at Las Vigas, Ver., there are almost as many early or autumnal frosts as late or spring frosts. The early ones cause damage in the region mainly to barley, late ones affect corn, bean and potato while growing.

Figures 3 and 5 show the correlation between the northers that lash the Gulf of Mexico and the frosts at Las Vigas, Ver. There is a positive correlation, significative at 1%, indicating that frosts are directly related to northers. This can be verified with the synoptic charts shown in Figures 6, 7 and 8 and the climatological data in Table II.

Figures 6, 7 and 8 and Table II show that the northers that affect the Gulf of Mexico lead to frosts in the crops region of Las Vigas, Ver., two days after passing the front.

It is recommended that when the Forecast Center of the Gulf of Mexico registers a strong norther, at Las Vigas certain steps must be taken to protect agricultural crops (Bagdonas e⁺ al., 1978), mainly if they are in the growing or flowering stages.

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