Atmósfera (2004) 127-150

Evaluation of climatic forecasts of rainfall for the Tlaxcala State (México): 1998-2002

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RESUMEN

En el segundo semestre de 1997, se implementó el proyecto de investigación "Utilización de pronósticos climáticos para actividades agrícolas en el estado de Tlaxcala". El objetivo principal del proyecto original fue el de caracterizar valores extremos de precipitación asociados a los eventos El Niño/La Niña, producir pronósticos mensuales de precipitación que fueran prácticos en la toma de decisiones para los cultivos de temporal. Esto último fue discutido con los productores cuyas necesidades y sugerencias fueron tomadas en cuenta, considerando un pronóstico lo más extendido posible. De esta manera los pronósticos se tornaron "Pronósticos vigilados por los productores". El método de ensamble de análogos observados fue aplicado para generar los pronósticos de 1998-2002. La evaluación de los pronósticos anuales y mensuales se presenta aquí. Los resultados muestran que se ha ganado conocimiento acerca del clima regional, como se refleja en la habilidad del método para pronosticar. Por último, se analiza el pronóstico 2003 para el Estado en términos de las anomalías de la precipitación.

ABSTRACT

During the second semester of 1997 the project "Utilización de pronósticos climáticos para actividades agrícolas en Tlaxcala" was instrumented with the purpose of aiding decision making in agricultural activities in the estate of Tlaxcala, México. The main objective of the project was to characterize extreme values of precipitation associated with El Niño/ La Niña events, to produce useful forecasts for decision-making. This was achieved through close contacts with the farmers whose specific needs were taken into account to the extent possible. In a sense such forecasts became "forecasts watched over by producers". The method of ensemble of analogs was applied to historical data. The evaluation of annual and monthly forecasts is presented here. The results show that knowledge about the regional climate has been gained as it is reflected by the skill of the method to forecast. The forecast for the region, for the year 2003 is analyzed in terms of the precipitation anomalies.

Key words: Tlaxcala, precipitation, ensemble of observed similar conditions

1. Introduction

Tlaxcala is the smallest Mexican state and it is located at aproximately 19° N latitude, 98° W longitude as it is shown in Figure 1. Tlaxcala's climate shows great diversity due to its complex orography and different land uses from one region to another. These characteristics result in very different weather regimes among regions that manifest themselves from day to day. However, the climate of the region is, in general terms, modulated by factors of a larger spatial scale like the Intertropical Convergence Zone (ITCZ) and its perturbations, the easterly waves, the trade winds and hurricanes. All these processes contribute an average precipitatation of 400 mm during the summer (Fig. 2a) and an average of 30 mm during the winter (Fig. 2b). Their influence may last for a season or even a year. It is also clear that the state of Tlaxcala has only one good season for rain-fed agricultural activities.

Tlaxcala's climate is strongly influenced by the occurrence of events of El Niño or La Niña. These conditions can determine rainy winters and dry summers, or dry winters and wetter summers respectively. The climatology of precipitation indicates that under El Niño conditions there is an increase of 69% during the winter and a decrease of 12.5% during the summer. It is also known that under La Niña, precipitation decreases 61.5% in winter and increases 19.4% during the summer all with respect to normal conditions for both seasons. Morales and Magaña (1999) have also observed that during the presence of El Niño, the frost-free period is reduced. Although these conditions apply in general terms to the State the impacts vary significantly from region to region (Avila, 2002).

In the preparation of the forecasts, use was made of climatological analogs. Anomalies of temperature and precipitation were examined, both for years previous, and for the El Niño or La Niña years themselves (dryer and warmer summers during El Niño, wetter and cooler summers during La Niña). From the analysis of these anomalies, ensemble of analogs corresponding to different conditions were produced to be used as forecasts (Morales-Acoltzi and Magaña, 2001).

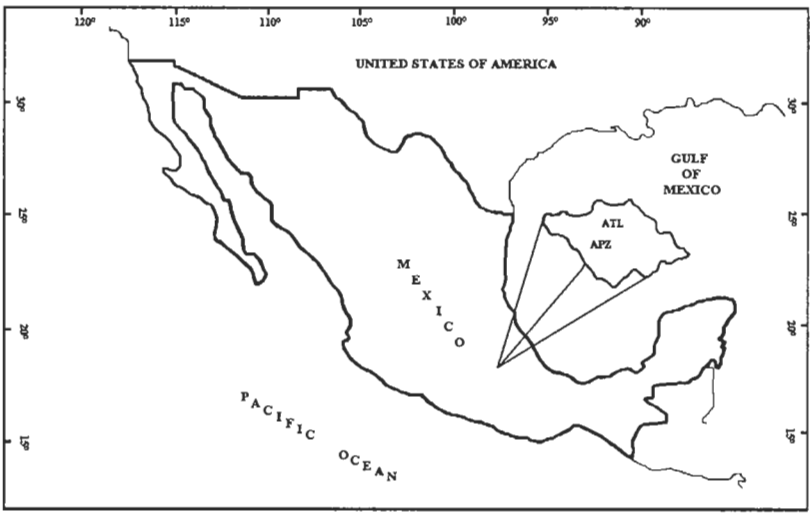

Fig. 1. Localization of Tlaxcala State and Atlangatepec, and Apizaco Stations.

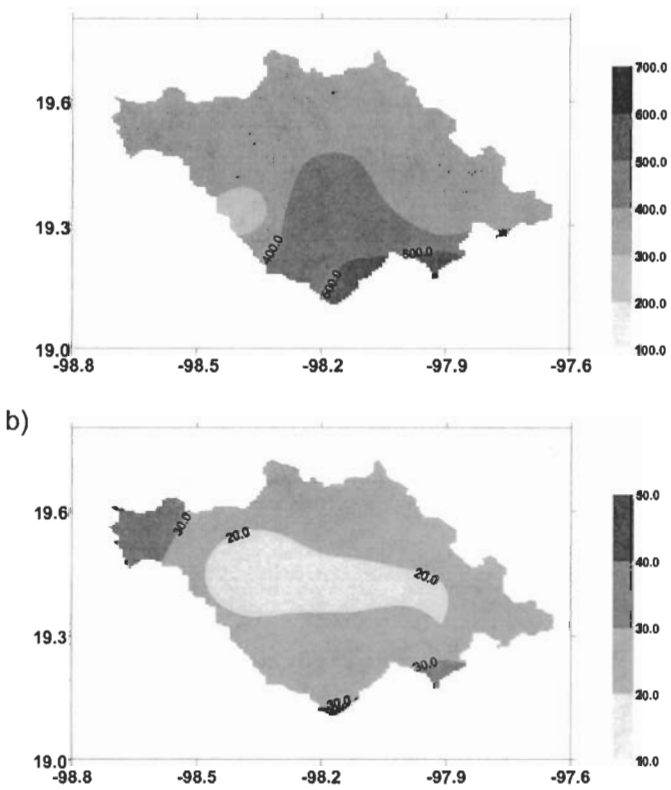

Fig. 2. Precipitation climatology: a) summer, b) winter.

In spite of the complexity of the climatic system of the State of Tlaxcala several precipitation forecasts have been issued with different space-time scales: in 1998, monthly from March to September; in 1999 again monthly from April to September (Magaña *et al.*, 1999). For the year 2000 and in response to suggestions by the producers, two-weekly and monthly forecasts from January to December were prepared (Pérez 2000). In 2001 (Magaña *et al.*, 1997; Hernández, 2001) prepared two-weekly forecasts from January to December, and for 2002, monthly and two-weekly forecasts from January to December were presented to the producers (Magaña *et al.*, 1999; Reyes, 2002). Every forecast was discussed with the producers before the planting season as to provide them time for planning and decisions making. The forecast for 2003 already presented to the producers is discussed here.

The objective of this work is to evaluate the skill of the forecasting method using an ensemble of observed analogs on the region, using five years of "forecasts watched over by the producers".

2. Data and methods

The knowledge that has been gained during recent years, relative to the importance that the phenomenon of El Niño has on the climate of Mexico, allows the use of statistical techniques to establish relationships between sea surface temperature (SST) anomalies and precipitation or temperature at a regional scale, using regression models. Even the use of analogs seems to be very useful. In order to produce forecasts using analogs taking into account El Niño and La Niña years or using statistical (regression) techniques, it is necessary to establish diagnostic relationships. These relationships with or without delays are built between observed or calculated (forecasted) SST anomalies in key regions (i.e. El Niño 3 region) and precipitation observations at a regional or even local scale. The SST anomalies are forecasted by large research institutions and are made available to the scientific community through the web.

Even if this forecasting technique is based on linear relationships between variables of a non-linear, highly complex system like the climate, the predictions turn out to be rather useful as first approximations. Even more, these predictions are better at the regional or local level than those provided by general circulation models (GCM) (Magaña and Quintanar, 1997).

To a large extent the success of the statistical models (diagnostic) depend on a good forecast of the SST anomalies. In the case of strong El Niño events the regional forecasts tend to be more reliable because the El Niño signal is very clear in the climate of Mexico (Magaña, 1999, Magaña *et al.*, 2003). This is good news because, after all these are extreme events, like those that occurred in 1997 and 1998, severely affecting regional climate, thus producing negative impacts on people's activities. Consequently, understanding the local effects of El Niño and La Niña is very important both, from a scientific and social points of view. "Forecast watched over by the producers" means that the producers keep an eye on the rainfall forecast each year, and they can compare with their own empirical methods, for example, "las cabañuelas", "la rueda Salomónica", "el calendario de "Galván", "el lunario", etc., depending on the particular region.

Precipitation time series obtained in 12 different climatological stations were used in the present analysis:

Apizaco, from 1940 to December 2002
Atlangatepec, from 1959 to December 2002
Españita, from 1977 to December of 2002
Huamantla, from 1987 to December 2002
Ixtacuixtla, 1974 to December 2002
Tepetitla, from 1974 to December 2002
Tlaxcala, from 1949 to December 2002
Tlaxco, from 1941 to December 2002
Toluca de Guadalupe, from 1979 to December 2002
Tocatlán, from 1966 to December 2002
Calpulalpan (San Marcos) from 1966 to December 2002
Zitlaltepec, from 1966 to December 2002

These stations are spatially distributed according to criteria established by the National Water Commission (Comisión Nacional del Agua). It is necessary to point out that the time series belong to a daily data-base. The dataset is available at Tlaxcala University, Campus Ixtacuixtla, Tlaxcala.

3. Results

The El Niño of 1997-1998 resulted in a serious production lose of grains in the State of Tlaxcala during the summer cycle of 1997. According to the results collected during the study "Utilización de pronósticos climáticos en actividades agrícolas en Tlaxcala", other El Niño events have modulated the productivity of the State, very notoriously, the 1982-1983 El Niño.

Forecasts for Tlaxcala were produced for 1998 and 1999 (Perez, 1997; Orozco, 2000) using statistical methods. Correlations were calculated between local variables, temperature and precipitation, and variables of large scale: Pcp the precipitation, T_{700} the temperature at 700 mb, ζ_{500} the vorticity at 500 mb., and SLP the sea level pressure. From this information multivariate regressions were generated where the local (dependent) variable (temperature or precipitation) was calculated in terms of the values of the variables of large scale at certain locations (where the correlations were high and significant). Examples of these equations for Summer precipitation for the Apizaco (01) and Atlangatepec (02) stations are given as follows:

$$Pcp_{APZ} = 9.98\,gT_{700}(-92.5W45N) + 4.51\,gT_{700}(-95.5W - 12.5S) - 12.34\,g\zeta_{500}(-105W27.5N)$$

$$Pcp_{ATL} = 12.2\,gSST(-65W22.5N) + 5.1\,gSST(-95W22.5N)$$

The indexes refer to the region and the predictor variables are evaluated at the locations indicated between parenthesis. The two equations corresponding to places which are very close, are significantly different, this is due to the fact that, while Apizaco belongs to an open system where the wind blows very frequently Atlangatepec is located in an area where there is a rather large body of water (a dam) and it is surrounded by mountains.

For years 2000, 2001, and 2002 forecasts were produced with a non-linear focus, applying the method of ensemble of analogs (Toth, 1989). The forecast for the year 2002 in particular, was prepared using the observed analogs corresponding to those years utilized by Gray (2002) in his hurricane forecasts for the Atlantic and Pacific Oceans. In all forecasts fundamental importance was placed on the predicted temperature anomalies of the SST on the El Niño 3 region. For the year 2003, the forecast was made using an ensemble of observed analogs. The selection of the analogs was based on current conditions, those of the previous four months and the expected behavior of oceanic indexes in the Pacific and the Atlantic.

3.1 Analysis by year and season

1998 precipitation forecast

For the summer of 1998 the weakening of the El Niño (1997-1998) was foreseen for July or August giving way to the appearance of La Niña. Based on previously estimated diagnostic relationships it was possible to establish that as long as El Niño conditions prevailed, a drought (very dry conditions) would be present, but as soon as the El Niño conditions disappeared, precipitation would recover. Based on this forecast, in March of 1998, predictions of precipitation anomalies were issued for the State of Tlaxcala (at a local level) with the purpose of giving time to farmers to plan their activities. The results of these forecasts were very encouraging in view of the comparisons to what actually occurred during the summer of 1998. In every case the forecast was adequate, the delay in the initiation of the rains and abundant precipitation during the second half of the summer as was later observed.

Considering the state of the ocean on March 25, as the initial condition, the forecast for the SST anomalies during March-May (http://www.cpc.ncep.noaa.gov/products) indicated that a positive anomaly of 1.5 °C would still persist over a large area of the equatorial Pacific Ocean. This condition corresponds with an El Niño (warm) event; more precisely, to a weak El Niño. From June to August the forecast indicated a reduction in area of 20 % for the 1.5 °C temperature anomaly. For the following months (September, October) still a positive anomaly would persist indicating a further weakening of the El Niño without reaching normal conditions. If these conditions would actually materialize then a forecast for Tlaxcala could be issued.

In 1998 forecasts were emitted for different regions in Tlaxcala where climatological stations provided information against which comparisons could be made. For Tlaxco (Fig.3b) the forecast indicated that from March to October, precipitation would be below normal, recovering up to 80% of normal conditions by September. The observations revealed a deficit in precipitation from March to June and a slight recovery in July and August without reaching normal conditions.

In Apizaco during the same period (March to October), rain above normal conditions was expected for March, followed by a period of three months (April to June) with a 40% deficit below normal. July, August and September were expected with precipitation 25% above normal, turning to deficit (30%) again in October. The observations showed lack of precipitation from March to June and a recovery from July to September, insufficient for normal conditions (Fig. 3).

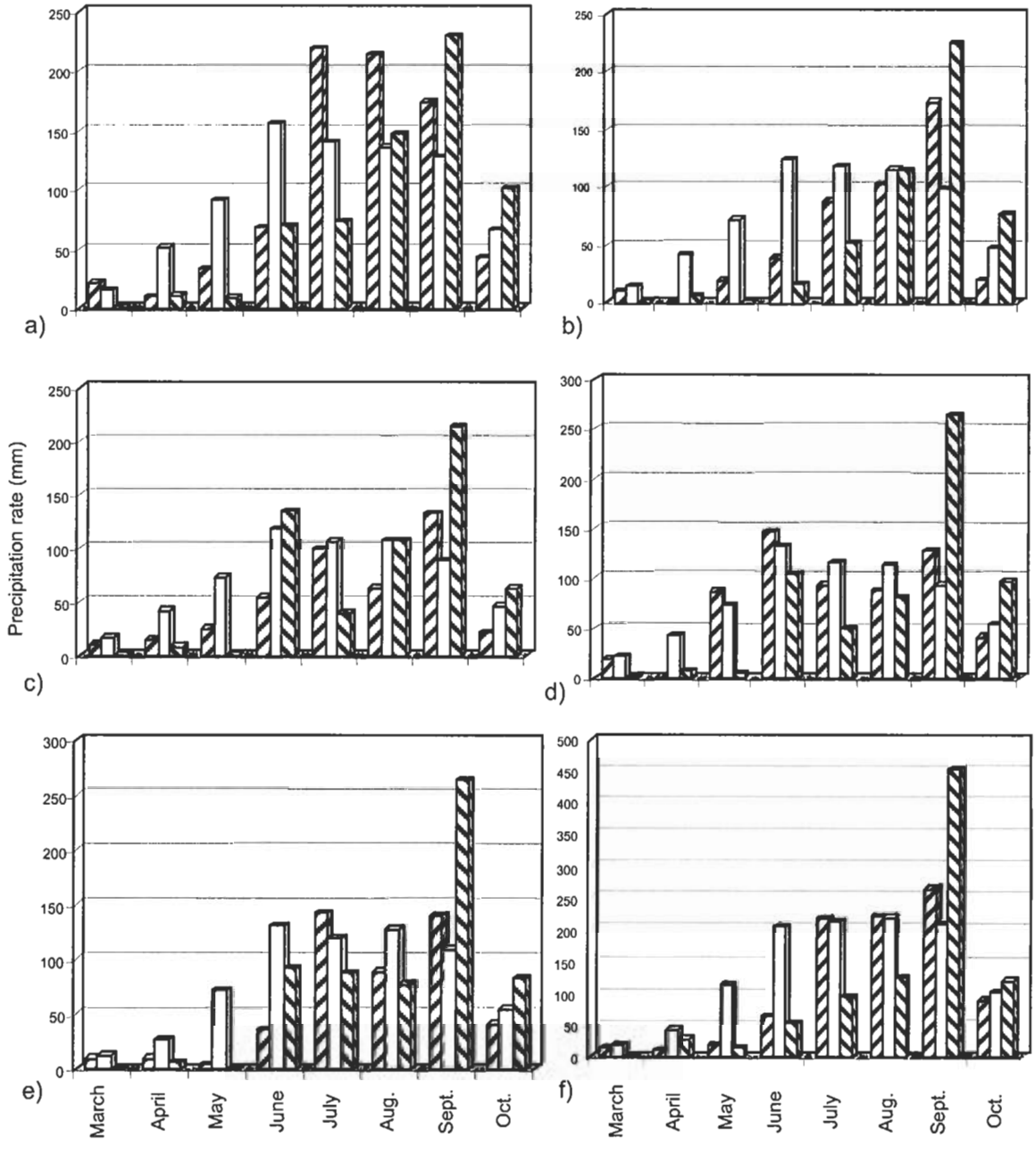

Fig. 3. Monthly prediction and evaluation of the 1998 precipitation forecast.
Bars from left to right: forecast, normal, predicted. Stations: a) Apizaco, b) Tlaxco, c) Huamantla, d) Calpulalpan, e) Ixtacuixtla, f) Españita.

In Huamantla the forecast pointed to relative dry conditions from March to August, rain excess (40% above average) in September and back to very dry (60%) conditions in October. In general terms the expectation was precipitation below normal for the whole season except in September. What actually happened agreed in general terms, as it is shown in Fig. 3c, a deficit in precipitation from March to June and a gradual recovery marked by the presence of a dry midsummer drought (canícula).

In Calpulalpan, March was expected with a slight deficit, April with a total absence of rain while May and June would have 10% more rain than normal (Fig. 3d). A canícula would be present during July and August (20% below normal) and September would be very rainy with 30% above normal conditions followed by a relative dry October (20%). Rains in Calpulalpan were expected to be very variable during the rainy season. Observations showed precipitation deficits from March to June, recuperation from July to September and the presence of a dry "canícula".

In Figure 3e, the forecasts and observations for Ixtacuixtla are compared. From March to August the predicted precipitation was below normal by 50%, an important increase of 15% was expected for July, turning to a deficit of 30% in August; September and October would show an increase and decrease of 20%, with respect to normal conditions. The observations indicated precipitation deficit from March to June with a recovery from July to September and the presence of an intense "canícula".

For the Españita station (Fig.3f) the forecast indicated that March would show precipitation 10% below normal; and for April to June the precipitation would be even lower (20%). The precipitation for July and August would increase, reaching 25% above normal conditions in September. Finally October would have a 10% deficit. In general terms a deficit in precipitation was expected from March to June and a surplus from July to September. Observations partially confirmed the forecast: low precipitation from March to June and recuperation during July to September.

1999 precipitation forecast; a summary

During 1999 La Niña phase of the ENSO was present. The forecasts for the SST indicated that the event would decrease with the temperatures of the ocean reaching normal condition by the last quarter. Taking into account this forecast allowed the preparation of predictions (using the methods indicated above) for the precipitation in the State.

The analysis for 1999 resulted in a recuperation of precipitation when compared to the El Niño event of 1998. In general terms the forecast indicated the presence of a dry April and precipitation in May on a band extending from the east to the southeast of the state with rains becoming generalized by June and July. During August the precipitation would decrease affecting the mountain ranges of Tlaxco (to the north of the state), Terrenate (to the northeast) and Altzayanca (to the east). For September an important increase in precipitation was expected all over the State. In summary, the State would enjoy plenty of water from May to September with a dry "canícula" in Apizaco (Fig. 4) El Carmen, Huamantla, Calpulalpan, and Atlangatepec.

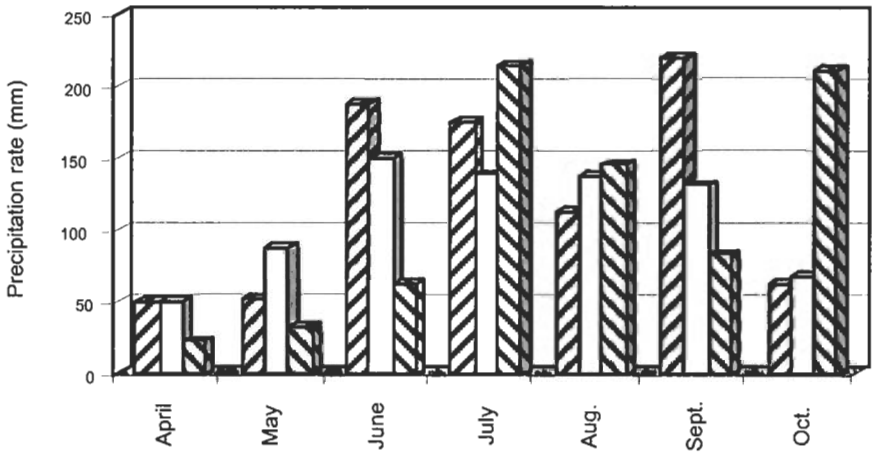

Fig. 4. Monthly prediction and evaluation of the 1999 precipitation forecast for Apizaco station. Bars as in Fig. 3.

2000 precipitation forecast; a summary

With information on precipitation and temperature anomalies of years prior to El Niño and La Niña events, ensembles of analogs were used to produce forecasts with a two-week time resolution.

The comparison of the forecast for the first semester of the year with observations, indicated agreement in sign, in relation to the normal value of the precipitation for that period. Important differences occurred in June and the first two weeks of July when more rain was observed than predicted. The opposite happened for the first two weeks of June. It should be emphasized that 2000 showed two "canículas". The first extending for a to two-week period in July, recovering in the first half of August and the second lasting a two-week period, (second half of August) turning to intense precipitation during the first half of September and finally decreasing marking the end of the rainy season. Agreement between predicted and observed precipitation from the second half of August to the end of the year was pretty good (Fig. 5).

2001 precipitation forecast for 6 stations; a summary

In the case of 2001 the agreement between forecast and observation was good for the first semester of the year although differences occurred during the second half of June when the forecasted rain was larger than the observed (Fig. 6). In fact the decrease of precipitation marked a first "canícula" that ended by the end of the month, giving place to a rainy July (above normal) and turning again into a new "canícula" that would last three weeks. The lapse between the two relative minimums was of one month in 2000 and of one month and a half in 2001.

According to the forecast the rainy season would begin in April, a "canícula" would be present

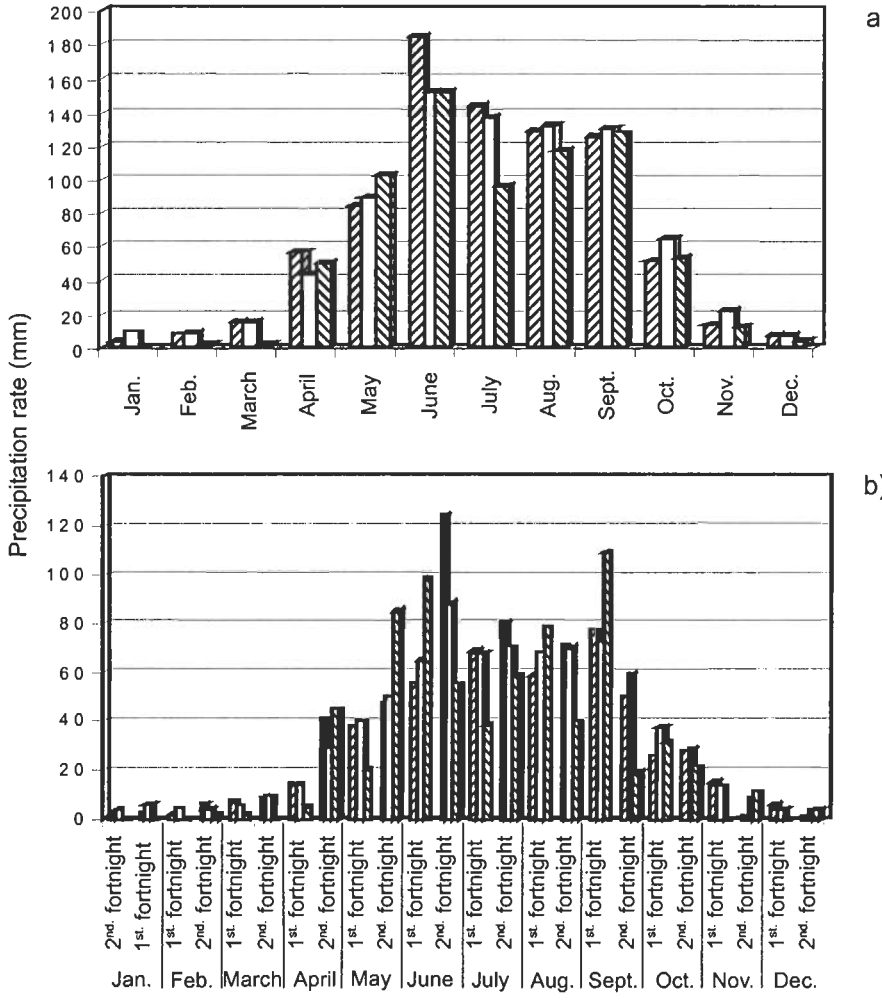

Fig. 5. Prediction and evaluation of the 2000 precipitation forecast for Apizaco station. Bars as in Fig. 3. a) Monthly, b) Fortnightly.

from the first half of July to the first half of August ending in the second, the precipitation would be slightly above normal during September and October. The forecast was able to pick up the "canícula".

2002 precipitation forecasts for 12 stations; a summary

The comparison between the forecasts based on ensembles and observations for12 climatological stations is shown in Fig. 7. It is possible to say that the agreement in general terms is acceptable for the first semester of the year when the number of months correctly predicted exceeds incorrect ones. July and August seems particularly difficult for the forecast with August the most difficult. For September, the forecasts improves as well as for the rest of the year.

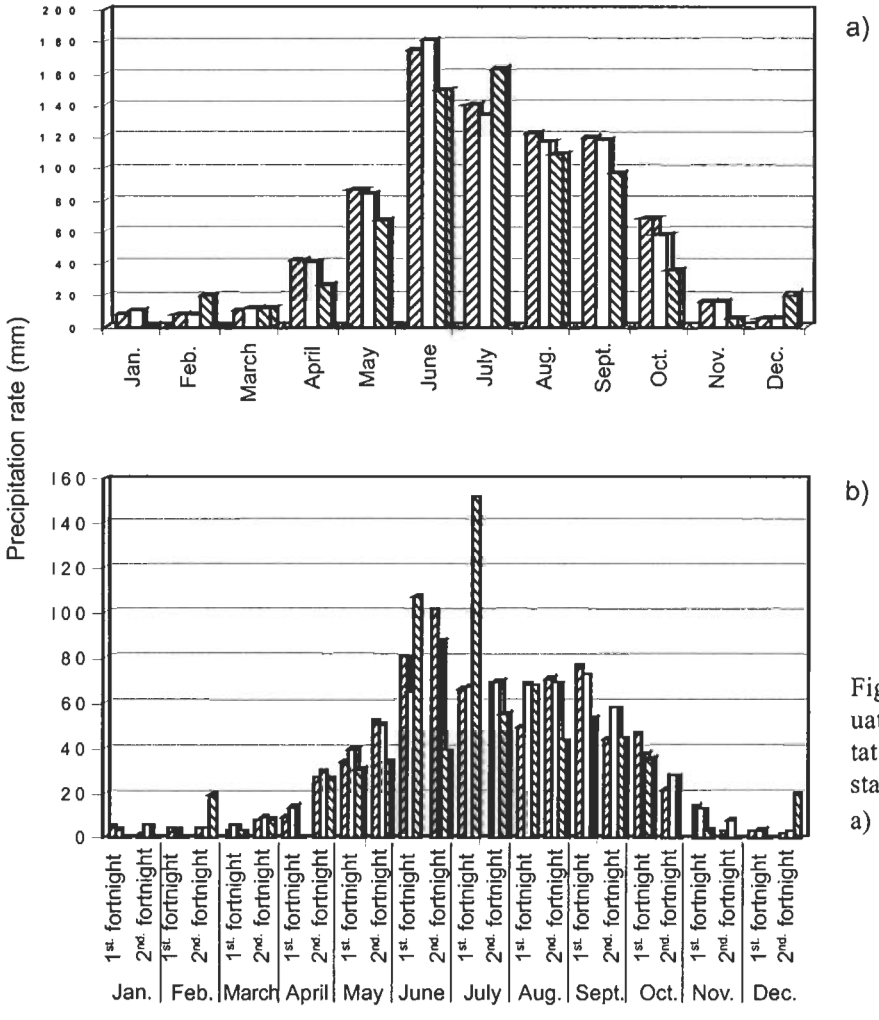

Fig. 6. Prediction and evaluation of the 2001 precipitation forecast for Apizaco station. Bars as in Fig. 3. a) Monthly, b) Fortnightly.

3.2 Evaluation of precipitation forecasts

Under El Niño conditions, the forecasts show a better skill due perhaps to the strong coupling between the ocean and the atmosphere that results in important modifications of the circulation at the global scale affecting regional and local conditions. Table 1 summarizes the results of a simple evaluation of the forecasts, consisting in assigning a one when the forecasts coincided with the observation and a zero otherwise. It is clear that the forecasts turned better (in general) for the first semester than for the whole year. For Apizaco two-weekly forecasts were prepared as petitioned by the producers. The results show that useful forecasts can be produced with similar skill to the monthly ones.

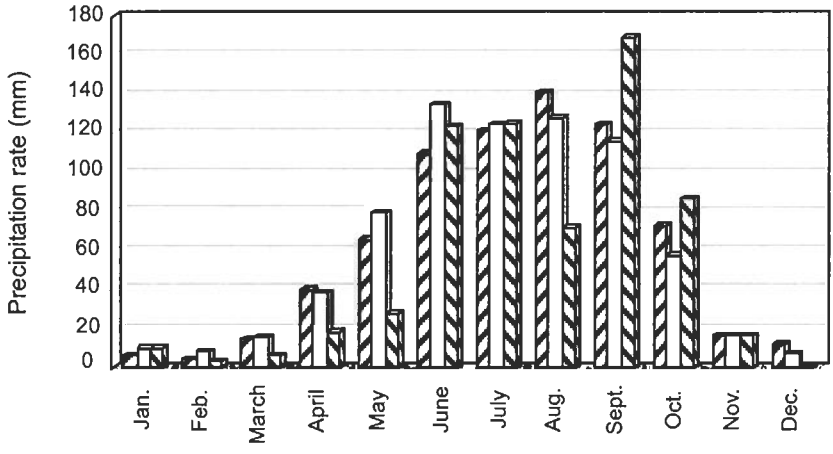

Fig. 7. Prediction and evaluation of precipitation forecast, areal average of the twelve stations. Bars as in Fig. 3.

Table 2 shows in summary, forecasted years, the number of stations that were utilized, their names, and the analog years employed to produce the forecasts. It should be pointed out that 1998 and 1999 were forecasted using statistical methods.

An attempt to regional forecast: State forecast

Eliminating local forcing, a forecast was produced for the entire State applying the same methodology. The results shown in Table I indicate a very acceptable skill and demonstrate that the method can be applied at the regional level. However this is not what most producers would prefer, rather, they would favor to have local forecasts. What part of the State of Tlaxcala is better represented by an area average of the twelve stations? In principle, it is expected that the area with the larger density of stations would be better represented. That is to say that the center-south then has more data. With the purpose of finding out the area of the state with an adequate forecast, a monthly march of the observed precipitation anomalies was generated. The result of this exercise confirmed that the zone of the state better predicted was the central one.

Precipitation forecast for 2003

Applying the method of the ensemble of analogs, a forecast for the twelve stations (Fig. 8) was prepared. Again the forecast is at monthly and annual levels according to the producers requirements. Two things are expected; first, the forecast will be better for the first semester, second it is expected that a second one will be produced at the end of June that can be used for the second semester.

The forecast indicates that precipitation will start in time and the quantity will be according to normal values for each station. A prolonged "canícula" will be present and in some cases will show

Table 1. Summary of the evaluation of the precipitation forecast.

Apizaco Station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CLIMBS	EVENT	1st. Sem.	2 semesters	Ensemble
1998			0	1	1	1	0	1	1	0			monthly	NIÑO	3/4 .75	5/8=0.62	Statistical
1999				1	1	0	1	0	0	0			monthly	NIÑA	2/3 .66	3/7=0.42	Statistical
	1	1	1	1	0	1	0	0	1	1	1	1	monthly		5/6 .83	9/12=0.75	Ensemble
2000	1+1	1+0	0+1	0+1	1+0	0+0	1+0	0+0	1+1	1+0	1+0	0+0	fortnightly		6/12 .5	11/24=0.45	Ensemble
	1	1	0	0	0	1	1	0	0	0	1	0	monthly		3/6 .5	4/12=9.41	Ensemble
2001	0+1	1+1	1+1	1+1	1+0	1+0	0+0	1+1	0+1	0+1	1+1	1+1	fortnightly	S/NIÑO A D	9/12 .7	17/24=0.71	Ensemble
	1	1	1	1	1	1	1	0	1	0	1	0	monthly		6/6 1.	8/9=0.88	Ensemble
2002	1+1	0+1	1+1	0+0	1+1	0+1	1+0	1+0	0+1				fortnightly		8/12 .6		Ensemble

San Marcos Calpulalpan Station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CLIMBS	EVENT	1st. Sem.	2 semesters	Ensemble
1998			1	1	0	0	1	1	1	0			monthly	NIÑO	2/4 .5	5/8=0.62	Statistical
1999				1	1	0	1	0	0	0			monthly	NIÑA	2/3 .66	3/7=0.42	Statistical
2000	0	0	1	0	0	1	1	1	0	0	0	1	monthly		2/6 .33	5/12=0.41	Ensemble
2001	0	0	1	1	1	0	1	0	1	1	1	0	monthly		3/6 .5	7/12=0.58	Ensemble
2002	1	1	1	1	0	1	1	0	1	1	1	0	monthly		5/6 .83	9/12=0.75	Ensemble

Huamantla Station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CLIMBS	EVENT	1st. Sem.	2 semesters	Ensemble
1998			1	1	1	0	1	0	1	0			monthly	NIÑO	3/4 .75	5/8=0.62	Statistical
1999				1	0	0	1	1	0	0			monthly	NIÑA	1/3 .3	3/7=0.42	Statistical
2000	1	0	0	1	0	1	0	0	1	1	0	0	monthly		3/6 .5	5/12=0.41	Ensemble
2001	0	0	1	1	0	0	1	1	1	0	1	1	monthly		2/6 .33	7/12=0.58	Ensemble
2002	0	1	0	0	1	0	1	0	0	1	1	0	monthly		2/6 .33	5/12=0.41	Ensemble

Ixtacuixtla Station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CLIMBS	EVENT	1st. Sem.	2 semesters	Ensemble
1998			1	1	1	1	0	1	1	0			monthly	NIÑO	4/4 1	6/8=0.75	Statistical
1999				0	1	0	1	1	0	0			monthly	NIÑA	1/3 .33	3/7=0.42	Statistical

Continues in the next page.

Table 1. Summary of . . .

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CLIMBS	EVENT	1st Sem.	2 semesters	Ensemble
2000	0	1	0	0	0	0	1	1	1	0	1	1	monthly		1/6 .16	5/12=0.50	Ensemble
2001	1	1	1	1	0	1	1	0	0	1	1	0	monthly		5/6 .83	8/12=0.66	Ensemble
2002	1	1	1	0	1	0	1	0	0	1	0	0	monthly		4/6 .66	6/12=0.50	Ensemble

Españita Station

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CLIMBS	EVENT	1st. Sem.	2 semesters	Ensemble
1998			1	1	1	1	0	0	1	0			monthly	NIÑO	4/4 1	5/8=0.62	Statistical
1999				1	1	0	1	0	0	1			monthly	NIÑA	2/3 .66	4/7=0.57	Statistical
2000	0	1	0	0	0	1	0	0	0	0	1	1	monthly		2/6 .33	4/12=0.33	Ensemble
2001	1	1	0	1	1	0	1	0	1	0	1	1	monthly		4/4 1	8/12=0.66	Ensemble
2002	1	1	0	1	1	1	0	0	0	0	1	0	monthly		5/6 .83	6/12=0.50	Ensemble

Table 2. Summary of the years of forecast, number of used stations, observed similar years.

Forecast	Number of stations	Stations	Periods	Similar years
1998	6	Apizaco		
		Tlaxco		
		Huamantla		
		Calpulalpan		
		Ixtacuixtla		
		Españita		
1999	8	Apizaco		
		Tlaxco		
		Huamantla		
		Calpulalpan		
		Ixtacuixtla		
		Españita		
		Atlangatepec		
		El Carmen T.		
2000	8	Apizaco	1944, 50, 56, 63, 68, 90	1944, 50, 56, 63, 68, 90
		Tlaxcala		50, 63, 68, 90
		Atlangatepec		63, 68, 90
		Tlaxco		1944, 50, 56, 63, 68, 90
		San Marcos Cal.		68, 90
		Huamantla		63, 68, 90
		Ixtacuixtla		1990
		Españita		1990
2001	6	Apizaco	50, 51, 52, 59, 60, 61, 62, 67	all
		Tlaxco	68, 69, 84, 85, 86, 99, 2000	from 62

Continues in the next page.

Table 2. Summary of the years . . .

Forecast	Number of station	Stations	Periods	Similar years
		Huamantla		from 62
		Calpulalpan		84, 85, 85, 99, 2000
		Ixtacuixtla		84, 85, 86, 99, 2000
		Españita		84, 85, 86, 99, 2000
2002	12	Atlangatepec	69, 76, 86, 93, 95, 96, 97	all
		Huamantla	98, 99, 2000	all
		Tlaxcala		all
		Españita		from 75
		Tlaxco		all
		El Carmen T.		all
		Calpulalpan		all
		Ixtacuixtla		from 75
		Tepetitla		from 74
		Tocatlán		all
		Zitlaltepec		all
		Apizaco		
2003	12	Atlangatepec		all
		Huamantla		all
		Tlaxcala		all
		Españita		87, 92
		Tlaxco		all
		El Carmen T.		all
		Calpulalpan		all
		Ixtacuixtla		87, 92
		Tepetitla		87, 92
		Tocatlán		all
		Zitlaltepec		all
		Apizaco		all

up as a double one as in Zitlaltepec, Huamantla, Tlaxco and Tlaxcala Capital. In Españita, Calpulalpan, Ixtacuixtla, Tepetitla and Tocatlán a relative minimum will occur in August.

Precipitation anomalies for 2003

A description of the negative precipitation anomalies forecasted in the State for 2003 is given as follows (see Fig. 9). In April the negative anomaly extends over the center-south part of the state; In June the anomaly covers from north to south and in July only the north. During August the canícula generalizes except for the north-south band, continues during September but it is not present in the south. By October there is a general deficit of precipitation that extends to November excepting the south. By December conditions turn to normal.

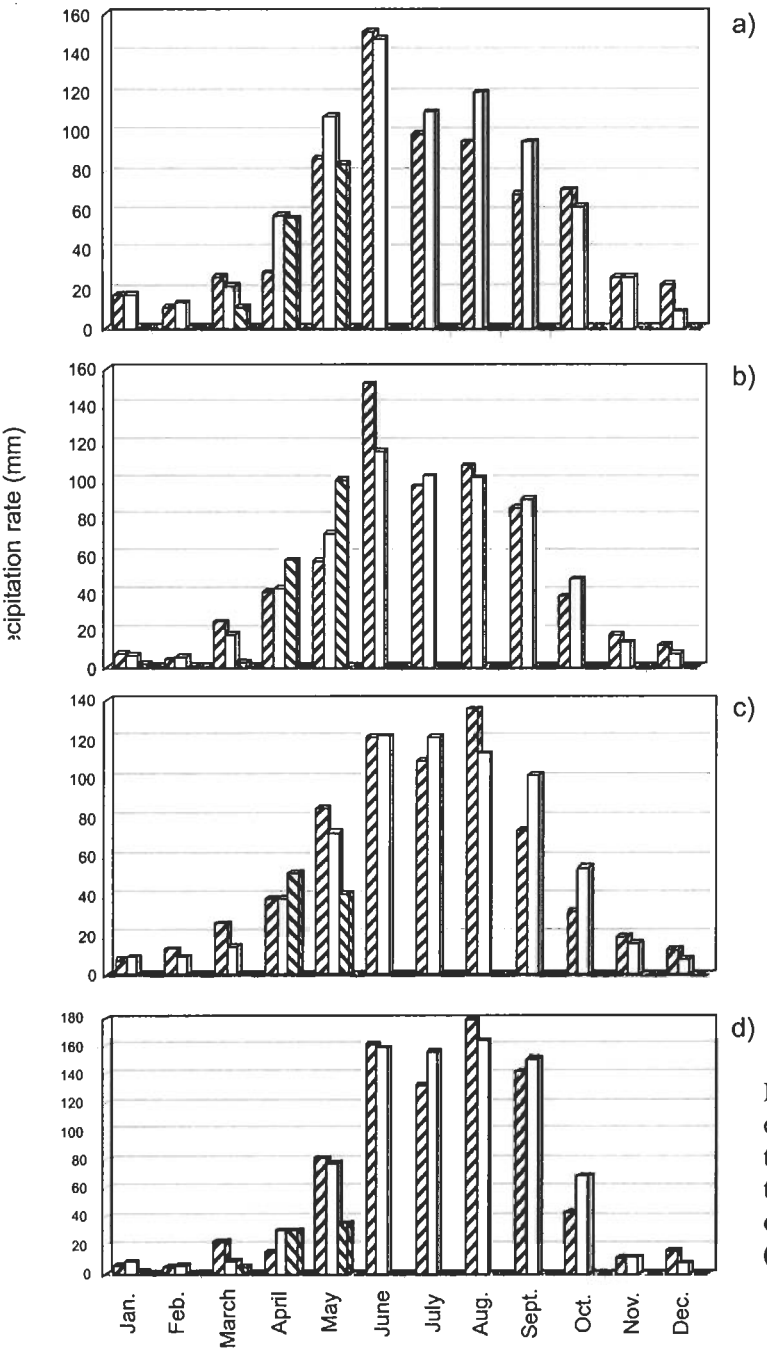

Fig. 8. Monthly prediction and evaluation of the 2003 precipitation forecast for stations: a) Zitlaltepec, b) Huamantla, c) Tlaxco, d) Tlaxcala. Bars as in Fig. 3. (Continues in the next page.)

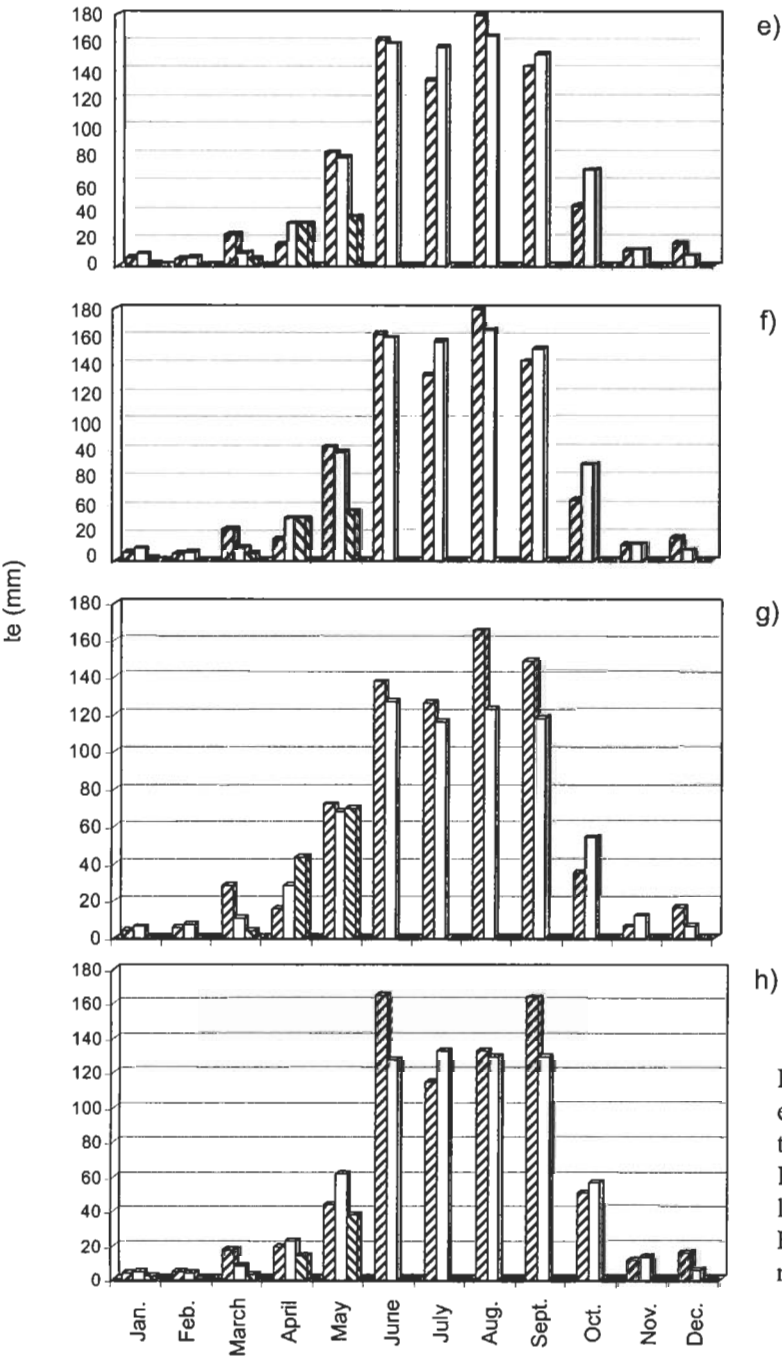

Fig. 8. Monthly prediction and evaluation of the 2003 precipitation forecast for stations: e) Españita, f) San Marcos Calpulalpan g) Ixtacuixtla h) Tepetitla. Bars as in Fig. 3. (Continues in the next page.)

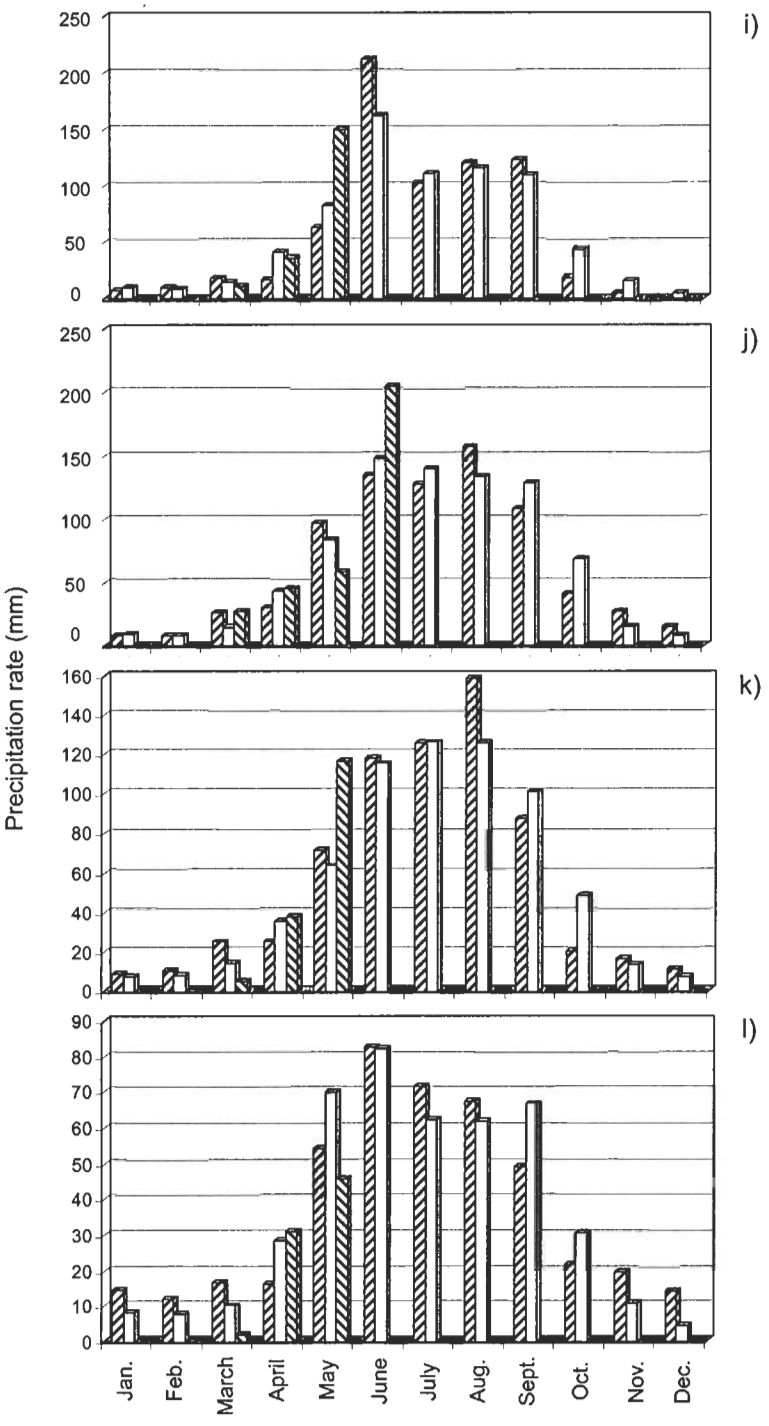

Fig. 8. Monthly prediction and evaluation of the 2003 precipitation forecast for stations: i) Tocatlán, j) Apizaco, k) Atlangatepec and l) El Carmen. Bars as in Fig. 3.

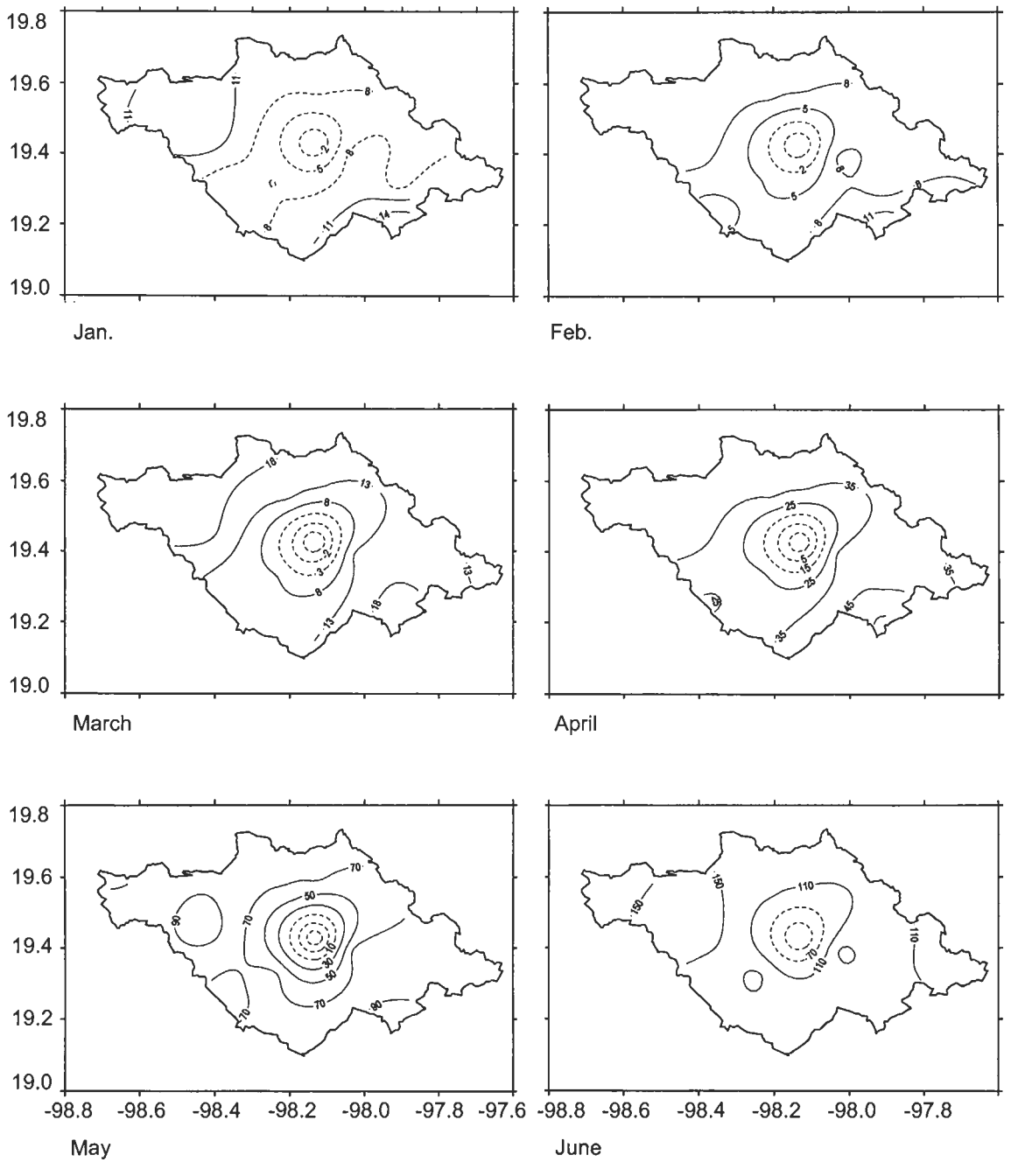

Fig. 9. Monthly forecasted anomalies for 2002 (continues in the next page).

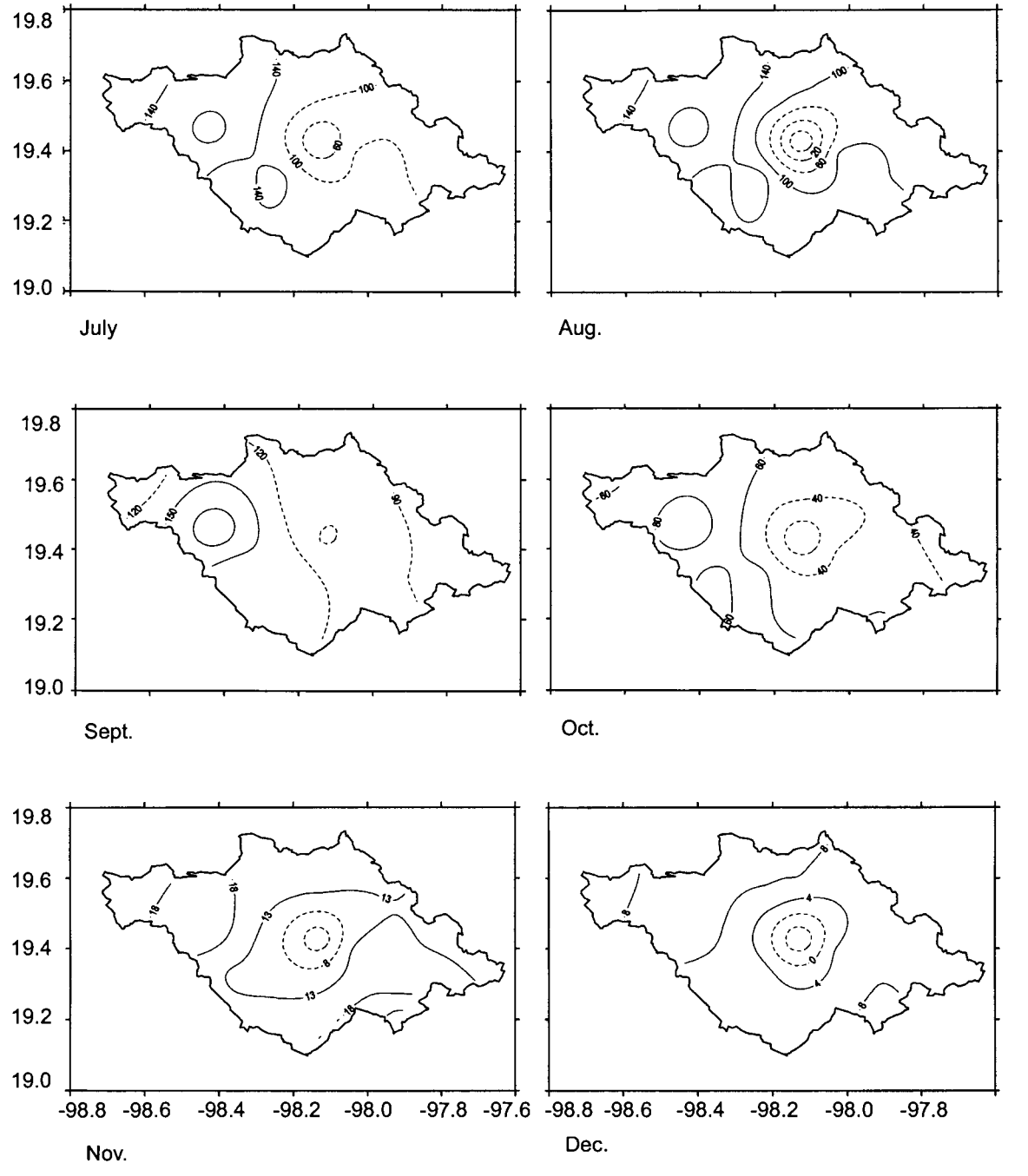

Fig. 9. Monthly forecasted anomalies for 2002.

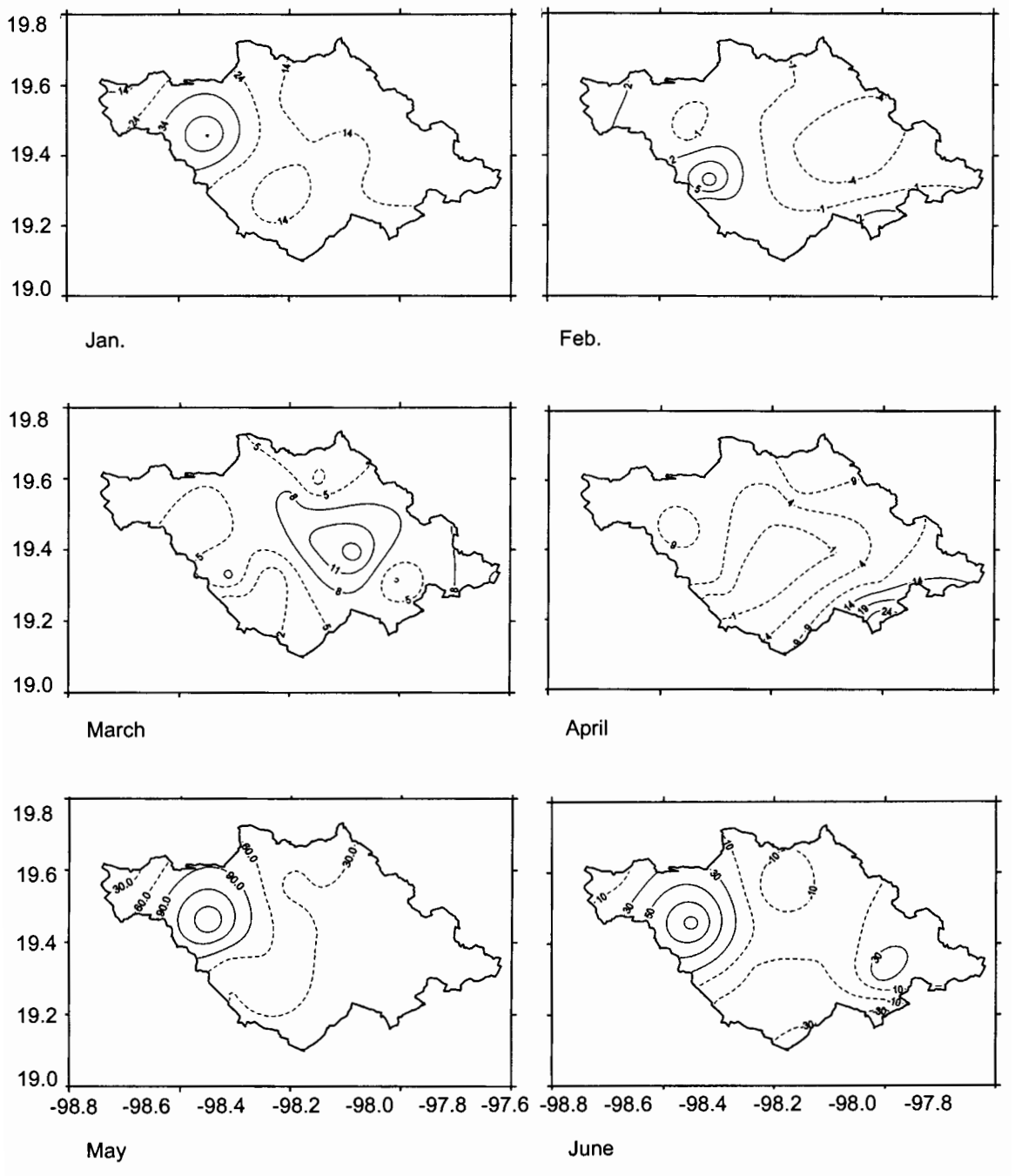

Fig. 10. Monthly forecasted anomalies for 2003 (continues in the next page).

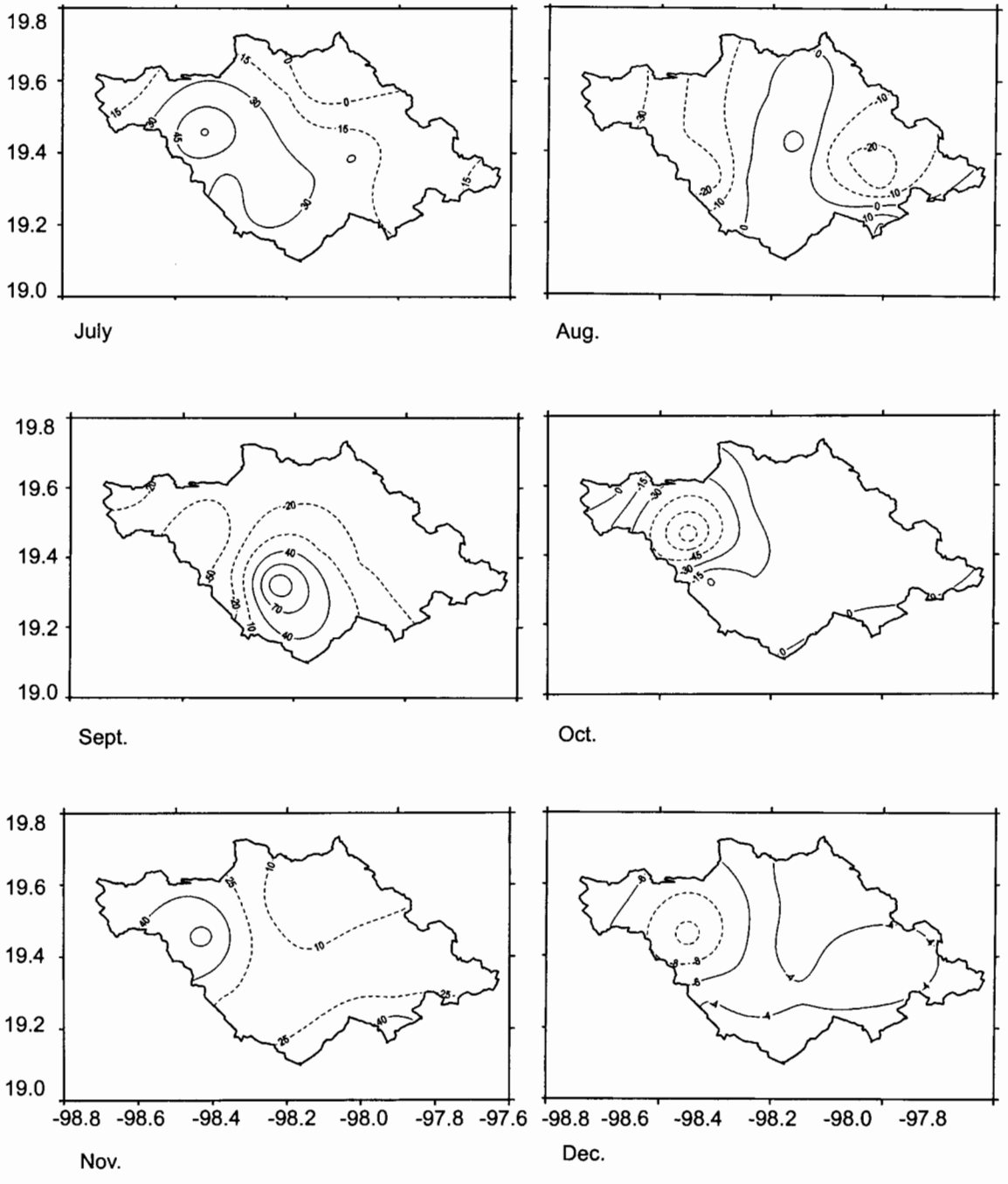

Fig. 10. Monthly forecasted anomalies for 2003.

4. Conclusions

In general terms the skill of the forecast was better when considering it valid for the first six months. This may indicate a limit to the predictability of the method, because the weather noise and deterministic chaos, representing the internal variability of the climate system, set the fundamental limits to the lead time (Neelin and Latif, 1998).

The skill of the method has been improved through the use of «ensemble of observed analogs». This method provides a basis for comparison and should be surpassed by deterministic, hybrid or other methods.

From a practical point of view the method is better than tossing a coin and used strategically by the producers could result in important economic savings.

The results suggest that the producers could benefit from a second forecast produced at the end of June that would update the previous one, given that the skill is better for a six months forecast.

Acknowledgments

This work was supported by the Instituto Nacional de Ecología (INE), and The USCSP (US Country Studies Program). Additional support came from the Fundación PRODUCE TLAXCALA, A. C., the UNAM (PAPIIT-IN111402), CONACyT (SIZA-960603003) through the Universidad Autónoma de Tlaxcala (UAT) and the authors would like to thank Gustavo Vázquez and Oscar Sánchez for their support.

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