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Climate variability and climate change in Mexico: A review

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RESUMEN

Se hace una revisión de la literatura sobre fluctuaciones, variabilidad climática y cambio climático en México. Los diversos enfoques utilizados para documentar las inconsistencias climáticas incluyen diversas escalas temporales, desde las paleoclimáticas hasta las que utilizan datos históricos y finalmente aquellos métodos apoyados en datos instrumentales. Para estudiar las anomalías climáticas en México, los diversos autores han intentado comprender la naturaleza y causas de la variabilidad del clima ligándola con los desplazamientos latitudinales de los grandes sistemas de circulación atmosférica de las latitudes templadas y más recientemente examinando el impacto de la variabilidad climática en el país y su relación con el fenómeno casi-global del Niño. Finalmente, en la presente década se han producido trabajos relacionados con el cambio climático global y su impacto en la población de México.

PALABRAS CLAVE: Cambio climático, México, revisión de variabilidad climática.

ABSTRACT

A review of research on climate variability, fluctuations and climate change in Mexico is presented. Earlier approaches include different time scales from paleoclimatic to historical and instrumental. The nature and causes of variability in Mexico have been attributed to large-scale southward/northward shifts of the mid-latitude major circulation and more recently to the ENSO cycle. Global greenhouse warming has become a major environmental issue and has spawned a large number of climate-change related impact studies.

KEY WORDS: Climate change, Mexico, climate variability review.

INTRODUCTION

The terms climate change, climate variation, climate fluctuation and climate variability are often used indistinctly. Different authors have proposed different definitions (Barring, 1993). However, it is generally agreed that the most general terms for climatic inconsistencies is climatic change or changes, which is used in everyday language. In this paper we will use the terms as employed by authors to designate climatic inconsistencies on different time scales. Most of the reviewed papers (mostly in Spanish) deal with the differences between long-term mean values of some climatic parameter (temperature or precipitation) over a specified interval of time, usually years or decades. In some cases, the reference time scale may be of the order of centuries.

Little research has been done on climate variability in Mexico in recent decades. Metcalfe (1987) attributes this situation to a lack of climatological data. The earliest available records date from the late 18th century when Antonio Alzate (1770) observed daily air temperature in downtown Mexico City over a nine month period in 1767 (Mosiño and Leyva, 1995). Observations of temperature and precipitation were made in and around Mexico City since the beginning of the 19th century for short periods of years. The longest rainfall record corresponds to the period 1855-1875 for Xochimilco, which at the time was a rural site south of Mexico City (Jáuregui, 1979). A few continuous records of temperature and precipitation are available from the turn of the century to the present.

These comparatively short climatological records have been used by various authors to gain some insight into the recent climates of Mexico. Other approaches including paleoclimatology, palinology and historical record analysis have also been undertaken. Without attempting to be exhaustive, this paper provides a brief description of research on climate change and climate fluctuations in Mexico.

THE PALEOCLIMATIC APPROACH

Klaus (1973) has examined climate change in Central Mexico during the last 40 000 years based on a geomorphological analysis by Heine (1973). Klaus found a negative correlation between the frequency of "Northerners" as strong winds that blow from the north in the Gulf of Mexico are known, and winter precipitation in the valley of Puebla, Central Mexico. Extremely cold winters are likely to be very dry. The high observed correlation of mean annual temperatures between Puebla and central Europe encouraged Klaus to reconstruct temperature fluctuations in Puebla since 1760. Lorenzo (1958), based on a paleographic analysis by Bryan (1948), also suggested that cold periods in Mexico are characterized by marked dryness.

O'Hara (1993) studied major changes in the level of Lake Pátzcuaro since 1388 until present. She found evidence of climate changes in central Mexico over the past 600 years. She suggested that the rapid drop in the level of Lake Pátzcuaro from the late nineteenth to the early twentieth century might be linked to severe drought conditions that occurred during the same period in the Bajío, the main grain producing region in Central Mexico. Lake-level fluctuations in the Basin of Mexico from paleoclimatological analysis led Metcalfe (1987) to conclude that the Aztec period (ca 1325-1521) was probably more humid than the present.

THE HISTORICAL RECORD

Since a correlation between climate and human history has been established for Europe, Claxton and Hecht (1978) have suggested a similar correlation could be developed for Latin America. However, few attempts have been made to correlate climate fluctuations in Mexico using proxy data from historical records. Dahlin (1983) examined the possible link between climate change and the collapse of the Maya culture in the drier part of the Yucatán peninsula. He blames repeated crop failures and decreased availability of water caused by severe drought conditions. A rainfall decline during the fifth century in the Yucatán peninsula could have been related to changes in the mid-latitude circumpolar vortex, as described by Sanchez and Kutzbach (1974) for the 1960's. Based on similar methods, García (1974) attempted to correlate modern climatological series from Europe and Mexico in order to explain the decline of the Teotihuacán culture after the fifth century, as due to a possible climate change.

Jáuregui (1995) attempted to correlate El Niño historical records by Quinn and Neal (1992) with series of droughts that have been recorded in Mexico since colonial times by Florescano (1980). These droughts were deduced from their impact on society (bad crops, higher prices of grains, social unrest). A significant correlation was found between El Niño events and drought occurrence in some parts of Mexico. This result, however, should be considered as preliminary; its main objective was to draw the attention of historians to the question of climate change in Mexico.

THE INSTRUMENTED PERIOD

More than four decades have elapsed since Wallen (1955) wrote what was probably the first paper on variability of the precipitation regime in Mexico. He associated the observed rainfall fluctuations in eight regions with the position of the subtropical high-pressure cells. A southward and easterly shift of the subtropical high pressure center over the Atlantic would be the main cause for the drying up of most of Mexico after the 1930s. Wallen proposed that a weakened trade wind current could account for the observed high precipitation in SW Mexico after the mid-thirties.

The question of whether the climate of the 1960's was analogous to that of the Little Ice Age in the American Tropics was raised by Sanchez and Kutzbach (1974). They found a zone of decreased precipitation across portions of the SE United States and northern Mexico in the decade. South of this zone, across west and central Mexico and Yucatán, there was a zone of increased precipitation. The authors showed that the 1960's was a decade of cold winters in the eastern United States due to a west coast ridge and an east coast trough in the jet stream configuration. Moreover, winter storm tracks shifted from their normal position across the U.S. at 35°N to about the latitude of Mexico City across Central America, resulting in higher than normal winter precipitation in central Mexico. They concluded that the trend of a southward shift in the northern hemisphere climate patterns appears to have been paralleled by a southward shift in the climate features over Mexico, Central America and northern South America.

Klaus and Jáuregui (1975) examined long-term fluctuations in rainfall in Mexico in terms of circulation patterns aloft. They concluded that a change from zonal to more frequent meridional circulation increased winter precipitation over eastern Mexico during the early seventies. Using instrumental precipitation records since the turn of the century, Jáuregui (1979) suggested that significant rainfall fluctuations have occurred in central and northern Mexico. These changes were a result of shifts in the latitude of the NE Pacific and North Atlantic high pressure cells.

Byrne *et al.* (1982) used area averages of seasonal rainfall in an effort to reconstruct climatic change in Mexico. They compared the temporal and spatial variability of two groups of stations with contrasting rainfall regimes: a central/southern Mexico group with long reliable records and high seasonal totals, and a group of California stations. The correlation they found was poor. However, pairs of individual stations in northwestern Mexico are strongly correlated with stations in southern California (e.g., Mazatlán summer rainfall with a 7-year lag of San Diego's winter rainfall). Byrne *et al.* (1982) conclude that area averages may be useful as a means of reconstructing climatic change. In spite of limitations, averages can provide a useful basis for comparison of rainfall regimes on the margins of subtropical deserts. Even though the Mexican area average is probably insensitive to short-term changes in rainfall, the summer rainfall curves of some Mexican stations support the conclusion that rainfall trends on the margins of subtropical deserts are principally a reflection of changes in the general circulation. (Byrne *et al.*, 1982).

REGIONAL CLIMATIC PATTERNS

It is generally agreed that the causal mechanisms of climate change are difficult to isolate. Sanchez and Kutzbach (1974), showed that long-term instrumental records of climate contain anomalous periods of the order of months, years or even decades that may be used to reconstruct patterns of climate fluctuations. Lamb (1967) first pointed out to an apparent change in the large-scale northern hemisphere atmospheric circulation during the 1960's. He showed that climate conditions since the 1960's have differed markedly from those which prevailed during the first half of the century. Up to this point, conditions were similar to the Little Ice Age, in the 17th and 18th centuries.

Sanchez and Kutzbach (1974) looked for corresponding changes in Central America during the 1960's. They found concurrent anomalies in the American tropics due to a southward shift of circulation features. When compared with the 1931-60 reference period, the 1961-70 average maps of anomalies showed cooler temperatures and lower rainfall for most of Mexico, except for the extreme south.

Lamb (1967) had noted that the climate of the 1960's featured a southward shift of major circulation traits including a southward shift of Arctic ice limits and of the North Atlantic Westerlies and the North Atlantic anticyclone. This mid-latitude pattern appears to have been paralleled by a southward shift of climate features over southern North and Central America (Sanchez and Kutzbach, 1974). Jáuregui (1996) has provided additional evidence of frequent deep penetrations of polar air masses into tropical Mexico in the 1960's. The prevailing explanation of the origin of these regional climate anomalies in Mexico involved changes in the intensity and extent of the circumpolar vortex, or shifts in the circulation features at the hemispheric scale. Little attention was being paid to the variability of tropical ocean temperatures, that is found to exert a major effect on rainfall in many parts of the tropics.

Rainfall variability in Mexico, and its causal relation to the El Niño events on the West coast of South America, were recognized in the late 1980's. Mosiño and Morales (1988) found that below-normal rainfall in Central Mexico was related to strong El Niños, while Niños of moderate strength were linked to abundant rainfall. Cavazos and Hastenrath (1990) concluded that El Niño events are related to increased winter precipitation in most of Mexico.

CLIMATE CHANGE IMPACT STUDIES

Several climate change-related impact studies have been attempted in Mexico as a result of an initiative by the U.S. State Department to create a "US Support for Country Studies to Address Climate Change". Thirty-nine papers on vulnerability of Mexico to climate change in areas of industry, agriculture, energy, human settlements ecosystems and coastal zones were presented in two country-study workshops that took place in Cuernavaca in 1994-1995 (Gay *et al.*, eds., 1994, 1995).

Table 1 shows the range of interest of participants in the two workshops. Most papers were on climate change impacts on agriculture, forestry and the desertification process, with emission inventories coming next.

Table 1

Papers presented at two Country Study Workshops (1994, 1995) on climate change and climate change impacts in Mexico

(1)	(2)	(3)	(4)	(5)	(6)	Total
19	8	2	2	3	5	39

1. Forestry, agriculture, sea level rise,
2. emission inventories
3. energy
4. industry
5. human settlements
6. regional climatic scenarios

Some studies dealt with scenarios of climate change for Mexico. Methods for interpreting the output of General Circulation Models (GCM) on a regional scale (Magaña, 1994) were proposed. Also, 30-year temperature and precipitation averages for 23 points in Mexico were elaborated in order to construct basic and regional scenarios (Conde *et al.*, 1994).

Other studies discussed the vulnerability to climate change and variability of Mexican agriculture, including regional case historie of interactions between climate variability and agriculture, and their impact on water availability as well as the possible effects of global warming (Liverman, 1991, 1994). Liverman proposes reducing the vulnerability to climate change and variation in Mexico by improving monitoring, modeling and forecasting of seasonal conditions, such as those related to El Niño. Worldwide interest in the ENSO phenomenon during the 1980's, has encouraged some efforts by local climatologists to relate this near-global event with climate variability in Mexico (e.g. Pereira *et al.*, 1994; Galindo, 1987; Salinas *et al.*, 1990; Reyes-Coca *et al.*, 1990; Lanza and Galindo, 1989; Gay and Conde, 1990).

The effect on human health of projected temperature increases from regional models for Mexico is difficult to predict. The increased stress in many urban areas will certainly affect productivity, human comfort and energy (Jáuregui, 1994; Jáuregui *et al.*, 1995, Aguilar, 1995).

Since the early 1980's a thermodynamic general circulation model developed by Adem (1991) has been used in various versions to compute climate changes due to atmospheric increase of CO_2 by using various improved versions of the model (Garduño and Adem, 1995). The purpose of this work is to estimate possible future long-term droughts in central Mexico due to surface temperature/evaporation increases and the decrease in precipitation predicted by the model in the same region.

CONCLUDING REMARKS

This paper attempts to review the limited number of papers that have been published on climate variability and climate change/impacts in Mexico. Given the geographical setting of the country, temperate-zone hemispheric circulation features play an important role in determining climate fluctuations in large areas of the country. It is only natural that most studies have focused on attempts to link the fluctuation in rainfall variability with major mid-latitude and subtropical circulation features.

Since global climate change moved to the forefront of the international attention, an increasing number of contributions on climate variability and vulnerability to climate change have appeared in the literature. New institutions such as the Interamerican Institute for Global Change Research (IAI) are promoting research capabilities to study climate variability in the Americas. Of particular interest for Mexico are the IAI programs to promote studies of the Interamerican Monsoon Circulations, and large-scale processes such as the Intertropical Convergence Zone. Such initiatives will hopefully promote further studies of climate variability and climate change in Mexico.

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