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Mexican forest fires and their decadal variations

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Abstract

A high forest fire season of two to three years is regularly observed each decade in Mexican forests. This seems to be related to the presence of the El Niño phenomenon and to the amount of total solar irradiance. In this study, the results of a multi-cross wavelet analysis are reported based on the occurrence of Mexican forest fires, El Niño and the total solar irradiance for the period 1970–2014. The analysis shows that Mexican forest fires and the strongest El Niño phenomena occur mostly around the minima of the solar cycle. This suggests that the total solar irradiance minima provide the appropriate climatological conditions for the occurrence of these forest fires. The next high season for Mexican forest fires could start in the next solar minimum, which will take place between the years 2017 and 2019. A complementary space analysis based on MODIS active fire data for Mexican forest fires from 2005 to 2014 shows that most of these fires occur in cedar and pine forests, on savannas and pasturelands, and in the central jungles of the Atlantic and Pacific coasts.

Keywords: Mexican forest fires; The Niño-Southern Oscillation; Total solar irradiance; Multi-cross wavelet analysis

1. Introduction

Forest fires have both natural and anthropogenic causes. There are two types of forest fires: (1) surface fires, which spread with a flaming front and burn senescent leaves, twigs, dry grass, leaf litter, fallen branches and other fuels located at ground level and (2) crown fires, in which burning occurs in the top layer of tree foliage and shrubs, often sustained by a surface fire. The latter is the most intense type of fire, often the most difficult to contain, needing strong winds, steep slopes and a heavy fuel load to continue burning. Forest fire behavior is influenced by different factors and their interaction, e.g., fuels, weather conditions and topography. A forest fire requires three elements: heat, oxygen and fuel. These three elements are designated as the "fire triangle" (Barenklau, 2001).

There are different methods of research and mathematical modelling of forest fires, which are used to analyze their prevention (Xodakov and Jarikova, 2011; Grifin, 1981; Nordemann et al., 2008). In this paper a time-frequency analysis is presented to find the frequency of the low and high Mexican forest fire seasons and also to find possible factors, both external and internal, involved in Mexican forest fires.

1.1. Mexican forest fires

Fig. 1 shows the vegetation in Mexico. It is well known that Mexico has a great deal of biological wealth in its tropical temperate forests and semi-desert climates; it ranks fourth worldwide in importance for the high diversity of its endemic species. This wealth is a national priority, a heritage that must be preserved for its enormous capacity to generate ecological, social and economic benefits. Forests must be protected against one of its most frequent enemies: forest fires (Cibrian et al., 2008).

Of the total Mexican surface area, 139.7 million hectares have some sort of forest cover. Just over 50% of the forest

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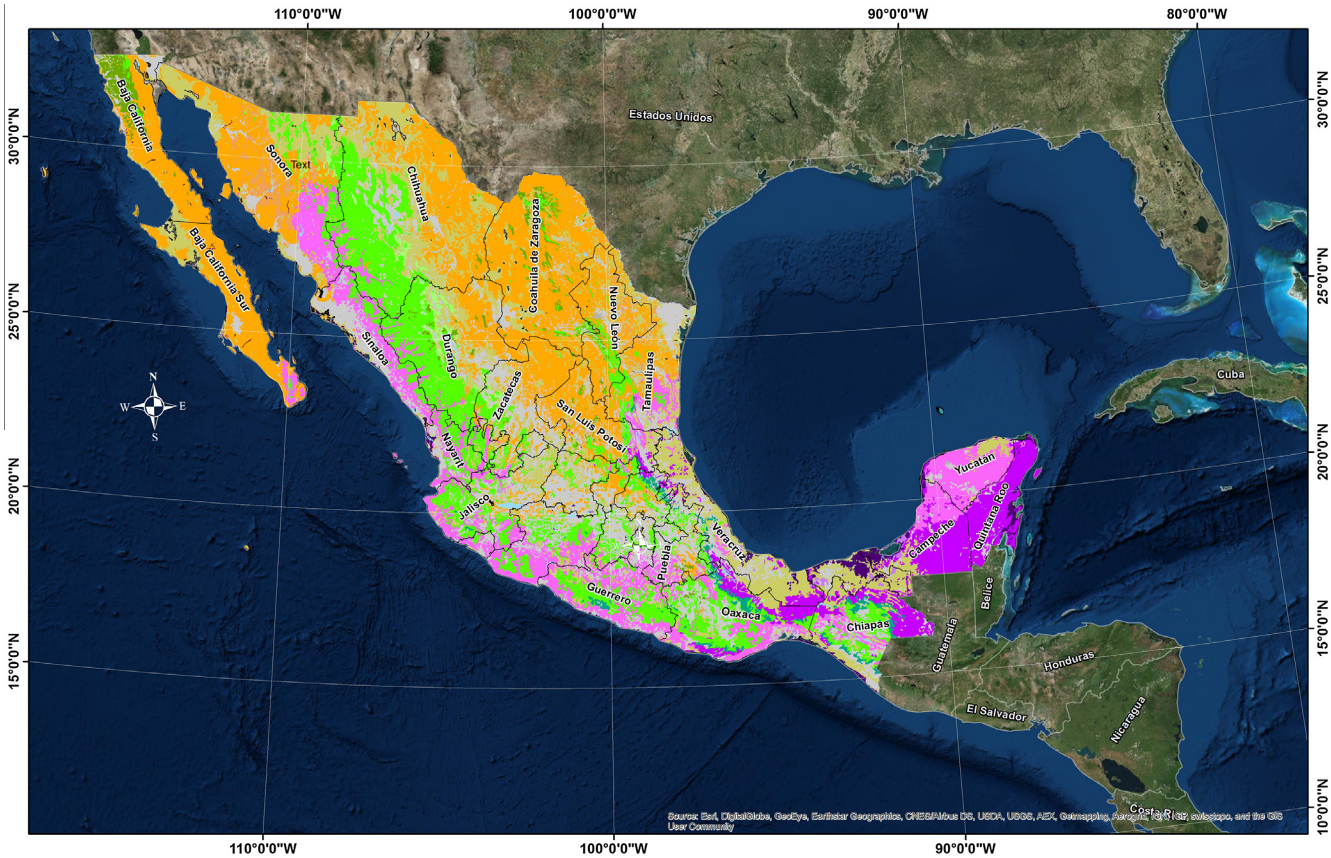

Fig. 1. Mexican vegetation: savanna (purple), middle jungle (pink), cedar and pine forest (green), pastureland (brown) and shrubbery (orange). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

area corresponds to fire-adapted ecosystems. Almost 36% corresponds to fire-sensitive ecosystems. Unfortunately, until 2007 Mexico also occupied the eighth place among countries that have lost forests due to forest fires (Juárez-Orozco and Cano-Santana, 2007). Almost 90% of them are surface fires and many occur during times of increased drought. The causes vary according to the region: in the center of the country, the cause is the burning of pasture and bonfires, whereas, in the southeast the main cause is the slash-and-burn method to prepare natural areas of vegetation for cultivation.

Drought refers mainly to long periods of the lack, scarcity or delay of rainfall and to extended periods of time with below-normal precipitation. Climatic variations on decadal, centennial to millennial timescales are very important in the analysis of historic drought. Using the Palmer Drought Severity Index for southeastern Mexico, Mendoza et al. (2007) found a quasi-decadal periodicity for the period of 1921–1987. Hodell et al. (2001) reported a drought frequency of 208 years and suggested that the Maya were affected by this periodicity in precipitation. Mendoza et al. (2006) found the periodicities of 7, 12, 20, 43, and 70 years by using a historical drought catalog for between 1502 and 1899 in the southeastern part of Mexico.

Around 8900 fires in Mexico occur annually, affecting 27% of the country's woodlands, other shrubs and grasslands or an average of 327,000 hectares of forests. The areas annually impacted by forest fires and the numbers of events vary widely depending on weather conditions and the social and economic conditions of the affected areas. In general, naturally caused forest fires are an important part of the dynamics of the ecosystems, but it is not the same when these natural disasters are of anthropogenic origin, which unfortunately cause 90% of these events (Juárez-Orozco and Cano-Santana, 2007). These kinds of fires constitute one of the significant causes of deforestation. Resources to combat them are very limited, significantly decreasing the affected forest areas, thus becoming a major factor in the gestation of a complex environmental problem (Torres Rojo, 2004).

One dramatic year, which set the tone, was that of 1998. That year, 14,445 forest fires were recorded, which affected 850,000 hectares. The scale was such that it reached twenty states of the country and some Central American countries; between May 14 and 20 of that year, a thick haze resulted from the particles released by the fires, which spread to the states of Texas and Florida in the USA, where health measures were taken and an environmental alert was decreed (Torres Rojo, 2004). Table 1 shows the Mexican states that had the highest incidence of fires during this event. In these states, the weather conditions for this disaster have been attributed to the ENSO phenomenon.

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