Mingyu WANG, Long SUN, Lifu SHU, Xiaorui TIAN

Spatial fluctuation of forest fires and their regional behaviors

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Abstract  Historical forest fire records from Alaska State (1950–2000), California State (1895–2001), USA and Heilongjiang Province (1980–1999), China were used to calculate the longitude and latitude of the annual burned area’s centroids for these regions. Fluctuation phenomena by year were analyzed using spectrum analysis. The results show that centroids of burned areas in these three regions are in a fluctuating condition that encircles the distribution center. The distribution centers are 151.11°W, 64.96°N in Alaska State, 120.02°W, 37.11°N in California State and 127.07°E, 49.59°N in Heilongjiang Province, respectively. The fluctuation of the burned area’s centroids in Alaska State and California State in longitude has obvious periodicity, and the periodicities are 4.2 years, 6.25 years in Alaska State and 6.24 years, 106 years in California State. The fluctuation of the burned area’s centroids in Heilongjiang Province has a periodicity both in longitude and latitude, and the periodicities are both 3.3 years, 6.67 years. Fluctuation of the burned area’s centroids in Alaska State and California State in latitude does not have periodicity, and big forest fires with low frequencies predominate.

Keywords  forest fires, fuel, global change, fluctuation

1 Introduction

Forest fires are a significant disturbance factor that influences the process of forest ecosystems (Agee, 1991; Specht, 1991). The conditions of forest fires’ occurrence had existed about 350–400 million years ago. Forest fires change the proportion of O2 and CO2, and the increase of the relative proportion of CO2 enhances the greenhouse effect (Lu et al., 2002). A forest fire is one of the major disturbance agents on a global scale that affects biogeochemical cycling, and plays an important role in atmospheric chemistry and the global carbon cycle (Thonicke et al., 2001). In many situations, forest fires have been one of the import parts of the ecosystem; dominant species have adapted to the fire cycle. In the past 100 years, fire frequency and intensity caused by humans has increased significantly (Specht, 1991).

In a rather long history, human beings put out all forest fires actively, whether anthropologic fires or natural fires. The long term putting out of forest fires has led to the unnatural accumulation of forest fuel. In this condition, once there is a forest fire outbreak, the fire is likely to develop into a big one. Forest fires may profoundly alter the structure of the landscape and the processes of ecosystems (Vázquez and Moreno, 2001). Disturbance plays an important role in shaping and maintaining land ecosystem, and forest fires are a necessary part for many forest ecosystems. Fire pattern and history are among the important study aspects of the fire regime. In a heterogeneous landscape, fire pattern results from the complex interaction among weather, ignition, vegetation, fuel moisture, and topography (Hargrove et al., 2000). Their interactions shape and promotes progress in the landscape in reverse (Li, 2000), and change the component and structure of species.

Human beings have recognized that global change is a complicated, systematic and a gradual problem which results from greenhouse gas emission. Global change has an impact on the precipitation distribution and air temperature change in different regions. It also influences the vegetation distribution. Global warming changes the litter amount and decomposition. The rising of air temperature has been changing the vegetation distribution, phonological characteristics and some factors that restrict litter decay, and influencing the function of matter cycling in forest ecosystems.

Global climate change is increasingly recognized as a complicated phenomenon involving multiple shifts in
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many dimensions of atmospheric function (Peterson et al., 2001). In recent years, more studies focused on the shift of the climate region, relative movement of the vegetation zone, and other responses to global warming. These responses include the change in biodiversity, rising of sea levels, movement of vegetation zone, and shrinking of glaciers. The impact of global change on forest fires includes changes in the burned area, fire frequency, and temporal and spatial fire pattern. In fact, the response of forest fires under the conditions affected by global change is the result of its coupling with vegetation, climate, and anthropogenic disturbance. The fluctuation of forest fire distribution along the longitude and latitude is the synthetic presentation of the response. Analysis of the quantity of the fluctuation of forest fires distribution in spatial dimension may educe a new evidence of global change.

Global change has influenced the distribution of natural and anthropogenic fire sources and influenced the spatial distribution of forest fuel and combustibility. Due to the continuous accumulation and rapid release of energy of forest fuel (Drossel and Schwab, 1992; Song et al., 2001), and the impact of other factors, forest fires present the phenomena of the fire cycle in a defined region and fluctuation in temporal and spatial space. Zhao’s (2002) study indicated that the vegetation zone in east of China will move forward north due to the impact of global change, especially, the deciduous forest area will diminish greatly. Thus, the change of vegetation zone will influence the distribution of forest fires to a certain extent. Wang (2003a, 2003b) studied the forest fires in Heilongjiang Province of China and found that centroids of burned areas have fluctuation in both the latitude and longitude dimensions. In a global scale, the behavior of this fluctuation in different region is still unknown. The study of this fluctuation and the sensitivity in different regions are meaningful and interesting areas of study. Whether or not the fluctuation exists in different regions and the magnitude of the amplitude of fluctuation will be studied in this paper.

2 Methods

Three regions are selected in this study in north hemisphere where severe forest fires occur every year (Fig. 1). These regions are Alaska, California, and the Heilongjiang Province in China. These three regions represent different latitude and longitude in the northern hemisphere, and details are found in fire records.

The historical records of fires in Alaska are from 1950 to 2000 while those of California are from 1895 to 2001 with records for 1897, 1899, 1904 and 1905 are missing. The historical records of fires in Heilongjiang Province are from 1980 to 1999.

Centroids are one of the most useful factors to represent objects in spatial distribution. Centroids represent the average location of the burned area and they function as the balance points of burned area. They can be calculated by the following equation:

\[
X_C = \frac{\sum W_i X_i}{\sum W_i}, \quad Y_C = \frac{\sum W_i Y_i}{\sum W_i}
\]

where \(i\) is discrete fire location, \(W_i\) is the weight of fire location or the distance from the fire location to the perimeter of burned area. \(X_i\) and \(Y_i\) are the coordinates of fire locations.

This study calculated all centroids of burned areas (Fig. 2). By calculation, we can simplify the complicated fire pattern effectively, and can present the fluctuation in temporal and spatial dimensions under the background of global change. Then we can study the fluctuation by spectral analysis.

Spectral analysis can be used to analyze the repeated spatial character in one dimensional or two dimensional space. Its fundamental thought is to use Fourier transform to decompose a serial of datum into sine wave of different frequency, different amplitude, and different starting point, and then select the best fitting wave equation. Spectral analysis determines the spatial

![Study area](Image)