Fluctuation of forest fires in space and their regional behavior

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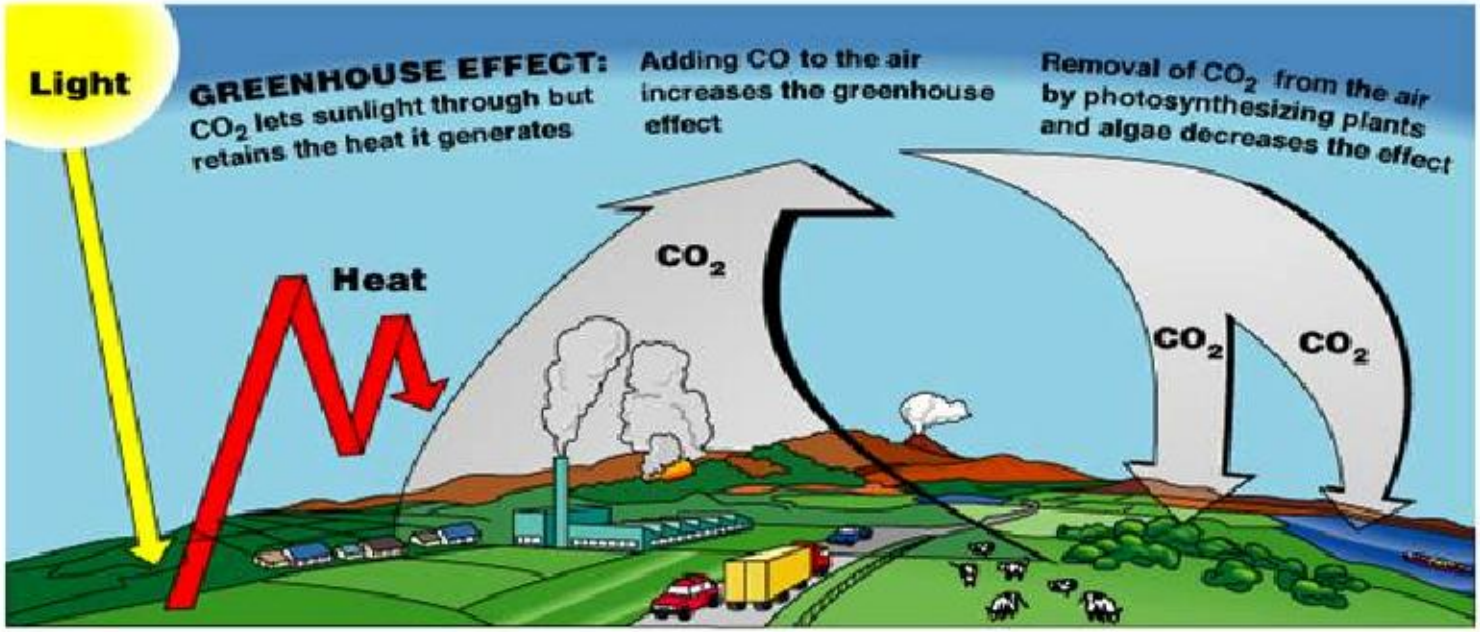
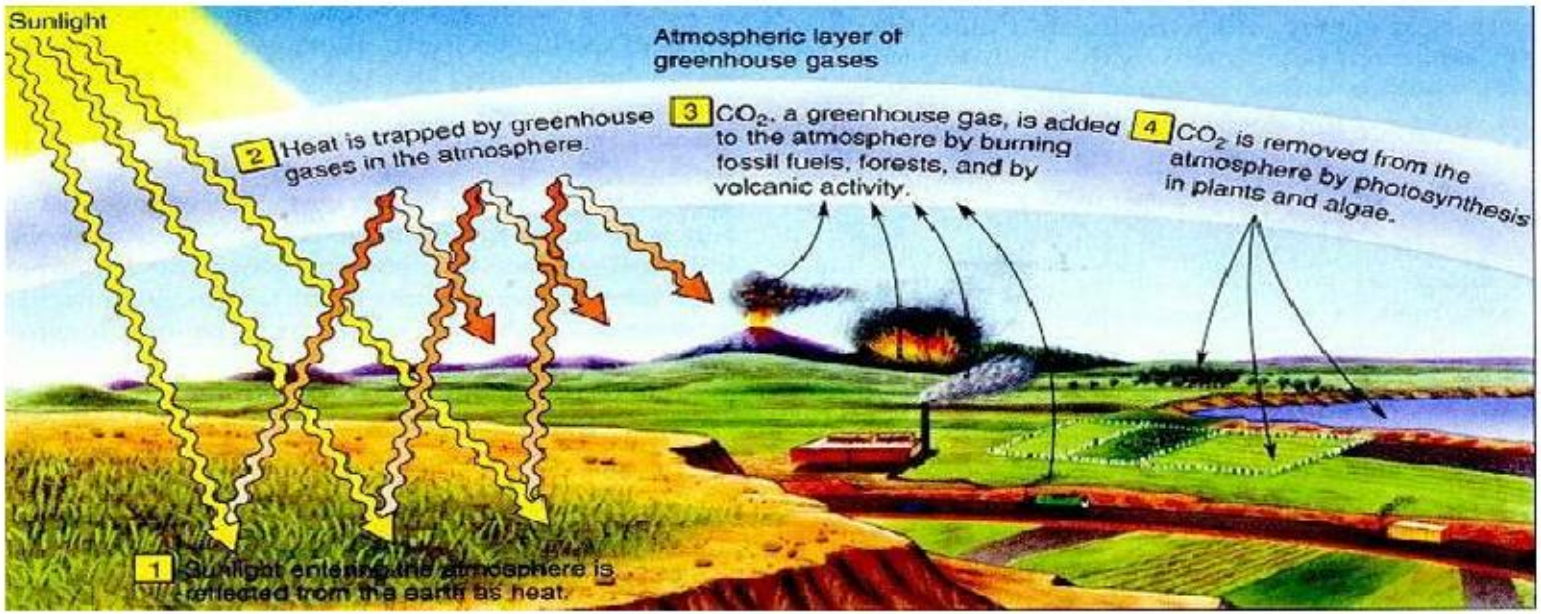
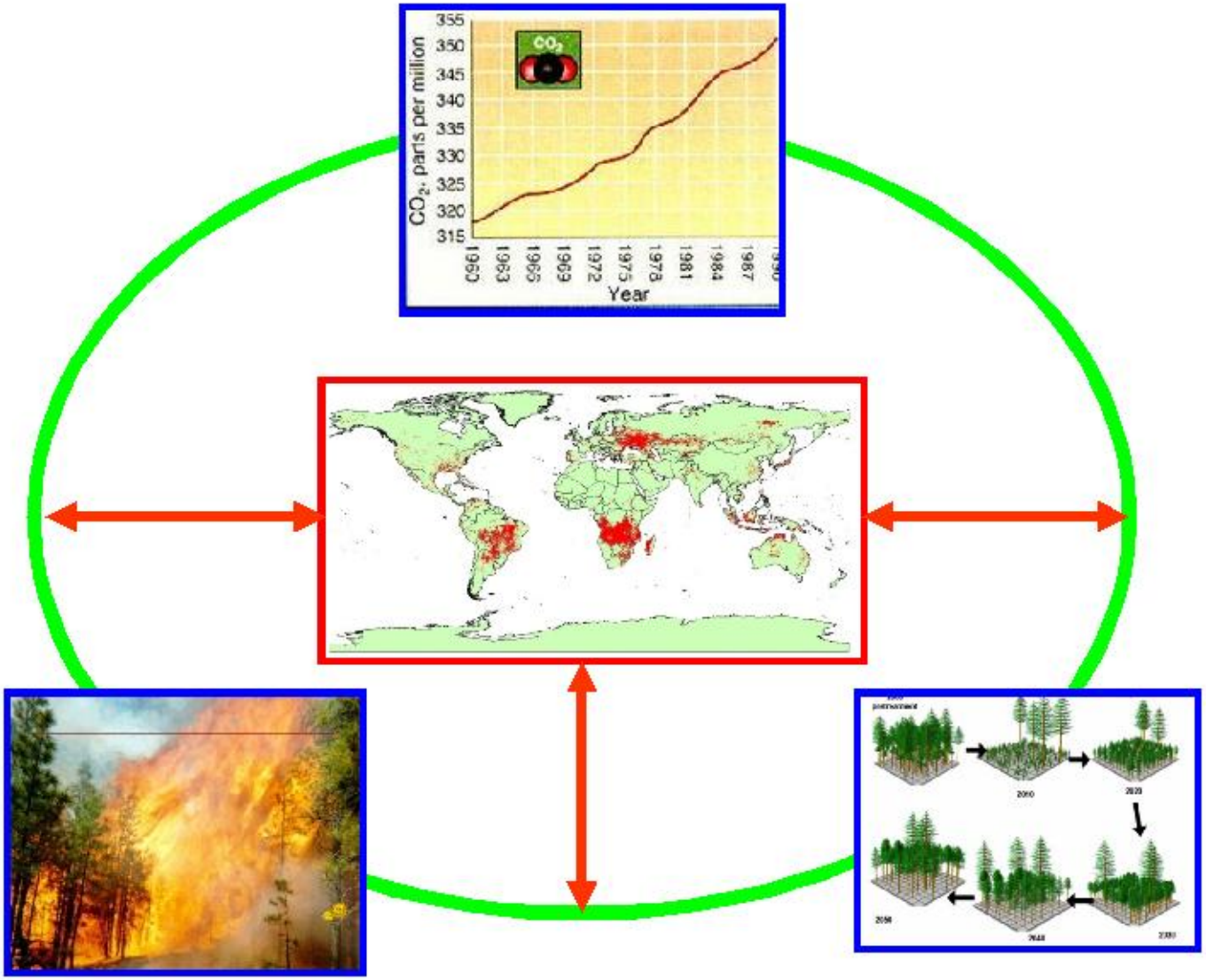
Introduction

- Forest fire is a significant disturbance factor that influences the process of forest ecosystem . The conditions of forest fires occurrence had existed about 350-400 million years ago. Forest fires change the proportion of O_2 and CO_2, the increase of relative proportion of CO_2 enhances the greenhouse effect. Forest fire is one of the major disturbance agents on the global scale, affects biogeochemical cycling, and plays an important role in atmospheric chemistry and the global carbon cycle . In many situations, forest fire has been one of the import part of ecosystem, dominant species have adapted to fire circle. In the past 100 years, fire frequency and intensity caused by human has increased significantly .



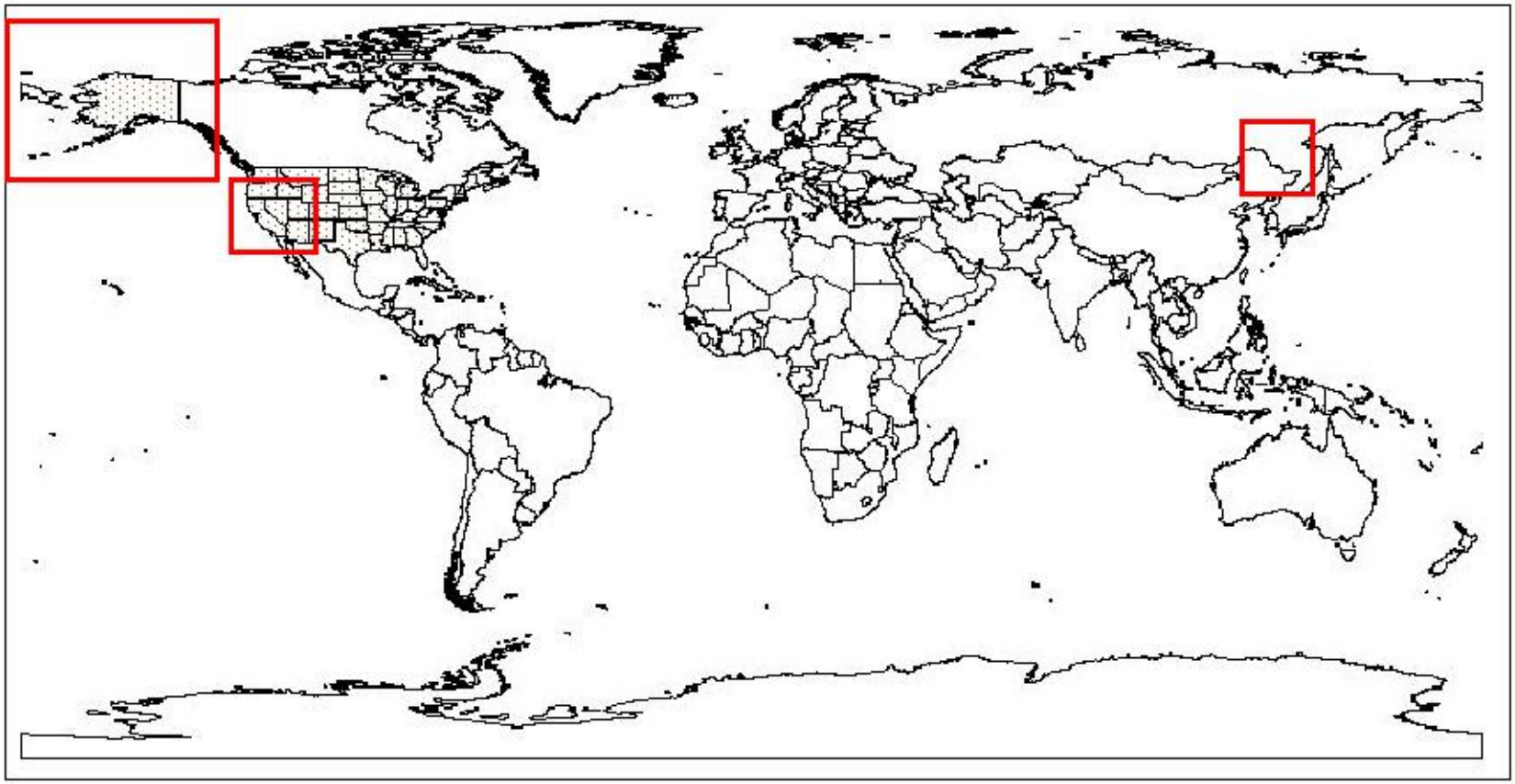
- **Global change has influenced the distribution of natural and anthropogenic fire sources, influenced the spatial distribution of forest fuel and combustibility. For the continuous accumulation and rapid release of energy of forest fuel, and the impact of other factors, forest fires present the phenomena of fire circle in a defined region and fluctuation in temporal and spatial space. Zhao(2002) study indicated that vegetation zone in east of China will move forward north under the impact of global change, especially deciduous forest area will diminish greatly, so the change of vegetation zone will influence the distribution of forest fires in a certain extent. Some scientists have studied forest fires in Heilongjiang Province, and found that centroids of burned area has fluctuation in latitude and longitude dimension. In global scale, the behavior of this fluctuation in different region is still unknown. Study this fluctuation and sensitivity in different region is meaningful and interesting. Whether or not the fluctuation exists in different regions and how much is the amplitude of fluctuation will be studied in this paper.**




CO_2, parts per million
355
350
345
340
335
330
325
320
315
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
Year
CO_2

Study area

- **Three regions are selected in this study in north hemisphere where severe forest fire occurred every year . These regions are Alaska, California, and Heilongjiang Province of China. These three regions represent different latitude and longitude in north hemisphere, and there are detail fire records.**



Methods

- Fire historical records of Alaska are from 1950 to 2000. Fire historical records of California are from 1895 to 2001, and records of 1897, 1899, 1904 and 1905 are missing. Fire historical records of Heilongjiang Province are from 1980 to 1999.
- Centroids are one of the most useful factors to represent objects spatial distribution. Centroids represent the average location of burned area, they are the balance points of burned area. They can be calculated by following equation.

$$X_C = \frac{\Sigma W_i X_i}{\sum W_i} \qquad Y_C = \frac{\Sigma W_i Y_i}{\sum W_i}$$

- Where, i is discrete fire location, W_i is weigh of fire location, it is the distance from fire location to perimeter of burned area. X_i, Y_i are coordinates of fire locations.
- This study calculated all centroids of burned area . By calculating, we can simplify complicated fire pattern effectively, and can present the fluctuation in temporal and spatial dimension synthetically under the background of global change. Then we can study the fluctuation by spectral analysis.

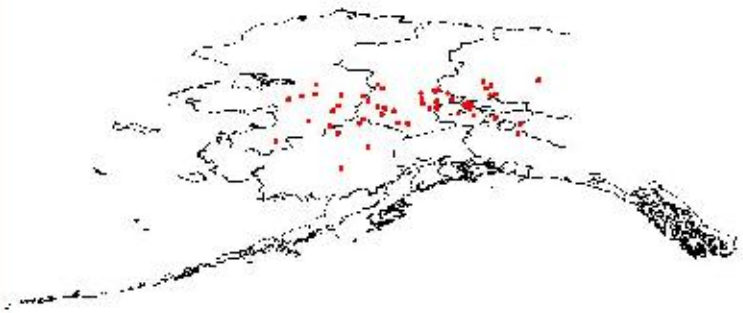
- **Spectral analysis can be used to analysis repeated spatial character in one dimensional or two dimensional space. Its fundamental thought is to use Fourier transform to decompose a serial of datum into sine wave of different frequency, different amplitude, and different starting point, and then select the best fitting wave equation. Spectral analysis determines the spatial pattern by comparing the centroids data with some known wave equation, and then periodic and random variety can be got from spectral periodogram.**

- **Where, is wave frequency, , are coefficients.**

$$Y = a_0 + \sum [a_k \cos(\lambda_k t) + b_k \sin(\lambda_k t)]$$

- **We analyzed fire historical records of three study area, calculated centroids of burned area in each year with ArcGIS software. We do not have fire perimeter records of Heilongjiang Province, so we buffered the ignition point with circles, and the area of circles is equal to the area recorded, then a serial of approximate fire mapping datum were constructed. Finally, we calculated the centroids of burned area, and analyzed the coordinates of centroids with spectral analysis, and got the period of fluctuation of centroids.**

Distribution of centroids of burned area in three regions



Alaska State

California State

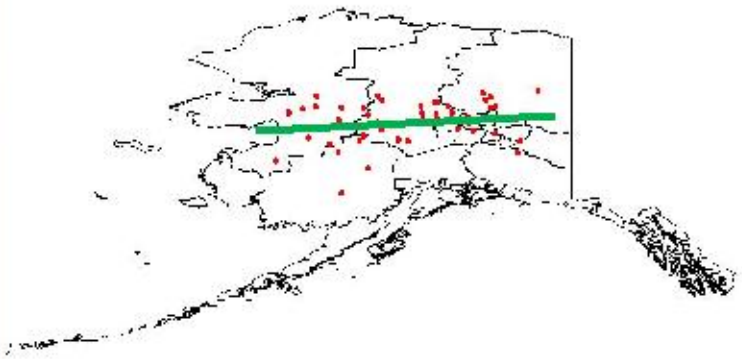
Heilongjiang Province

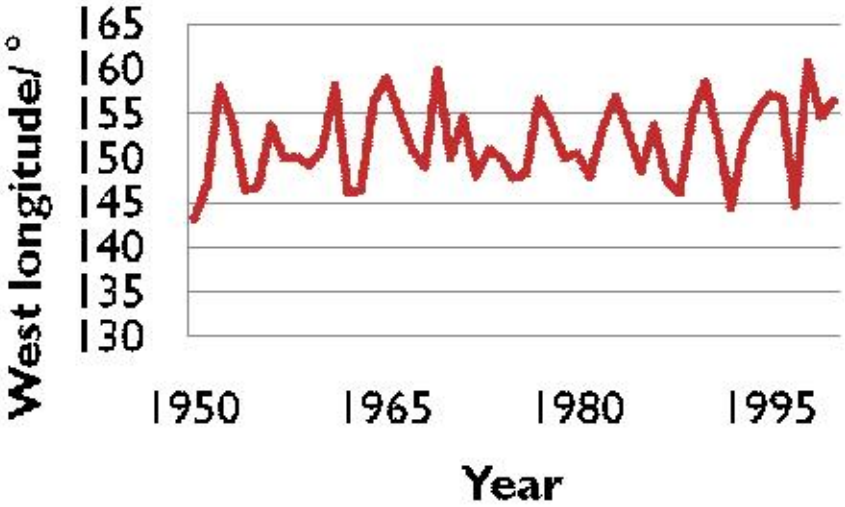
Spatial movement of fires

Fig.1 Fluctuation amplitude of burned area's centroids in three regions

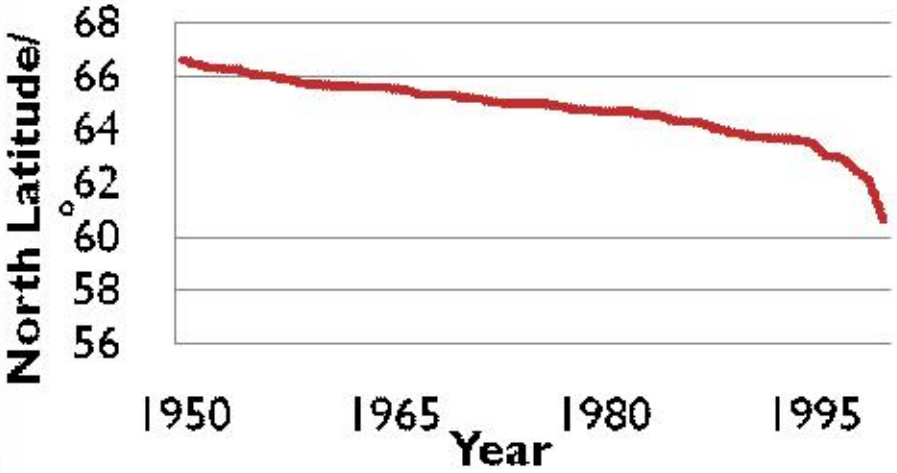
Regions	Amplitude/ °	Amplitude/ km
Alaska State, Longitude	17.67	422.2
Alaska State, latitude	5.94	457.2
California State, longitude	5.48	383.5
California State, Latitude	4.74	608.0
Heilongjiang Province, Longitude	5.60	276.5
Heilongjiang Province, Latitude	5.97	351.7

Alaska State



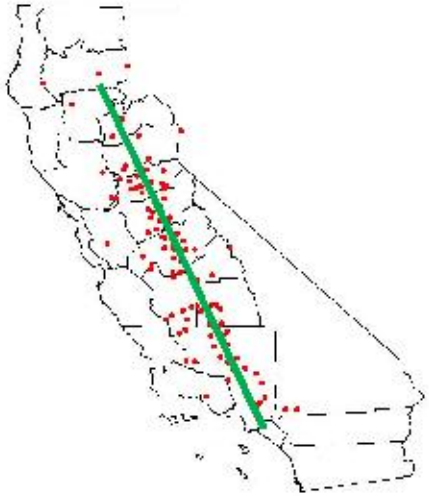


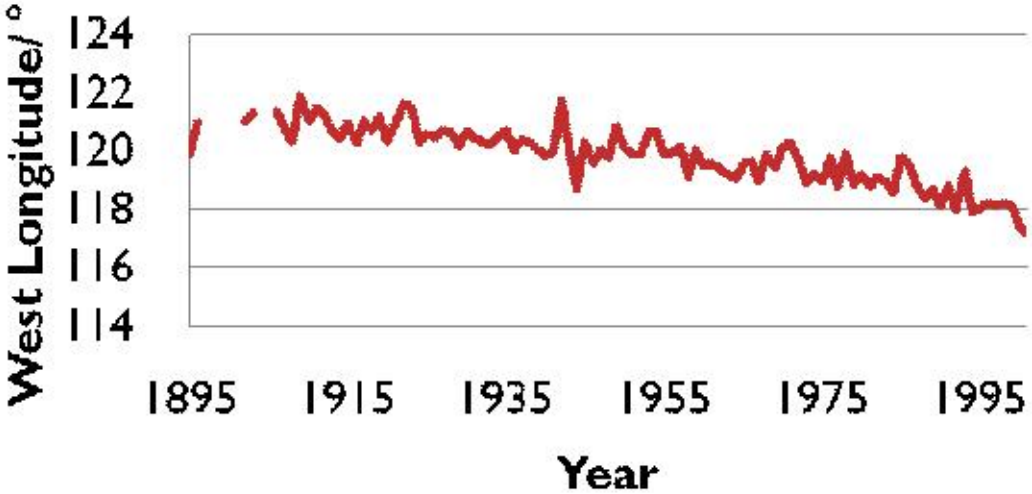
$y = 0.07x + 75.411$, $R^2 = 0.0711$, x is longitude, unit is °. Y is latitude, unit is °.



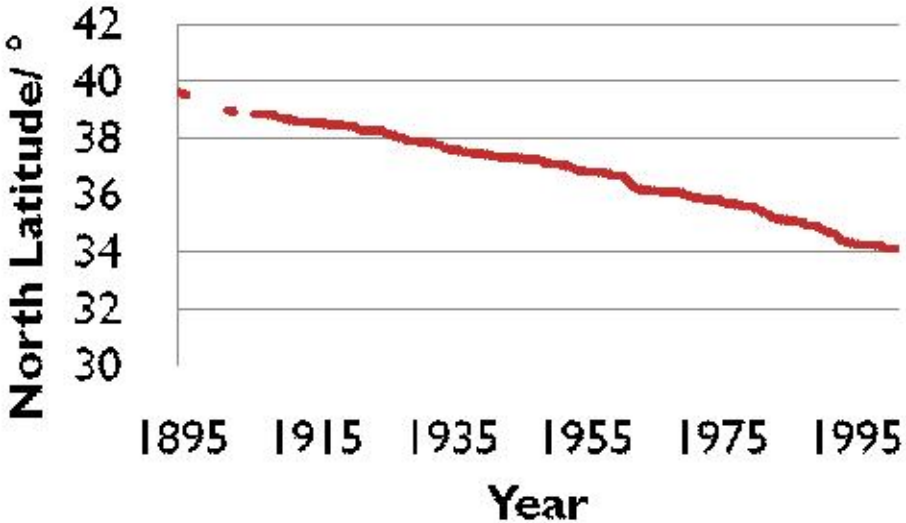
The maximal value of fire movement toward west is 160.89° W, and the least value of fire movement toward east is 143.22° W. In latitude direction, the maximal value towards north is 66.59° N, the least value towards south is 60.65° N.

California State



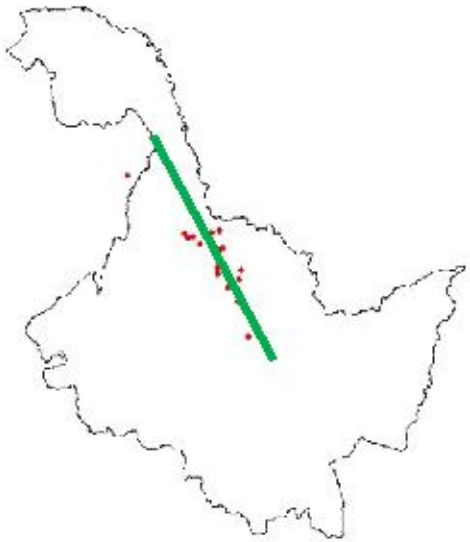


$y = 1.273x - 115.7$, $R^2 = 0.7607$, x is longitude, unit is ° .Y is latitude, unit is ° .

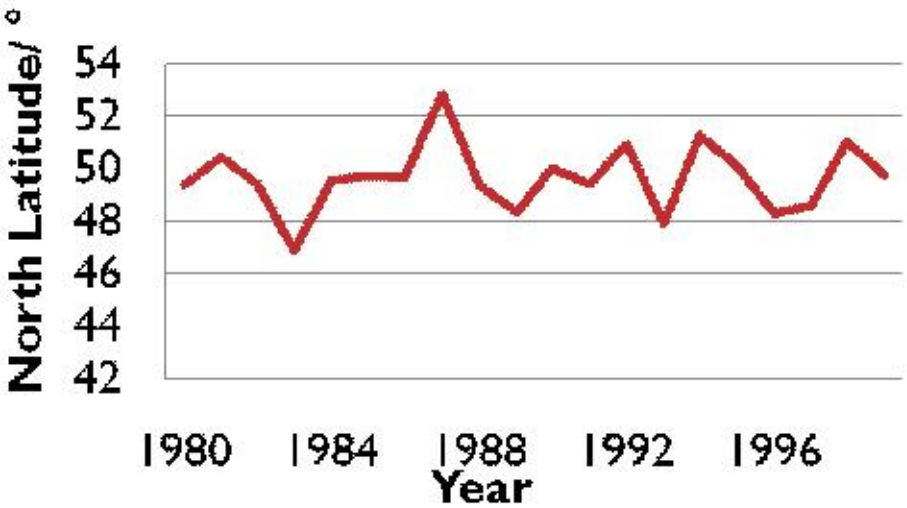


The maximal value of fire movement toward west is 121.90° W, and the least value of fire movement toward east is 117.16° W. In latitude direction, the maximal value towards north is 39.61° N, the least value towards south is 34.13° N.

Heilongjiang Province



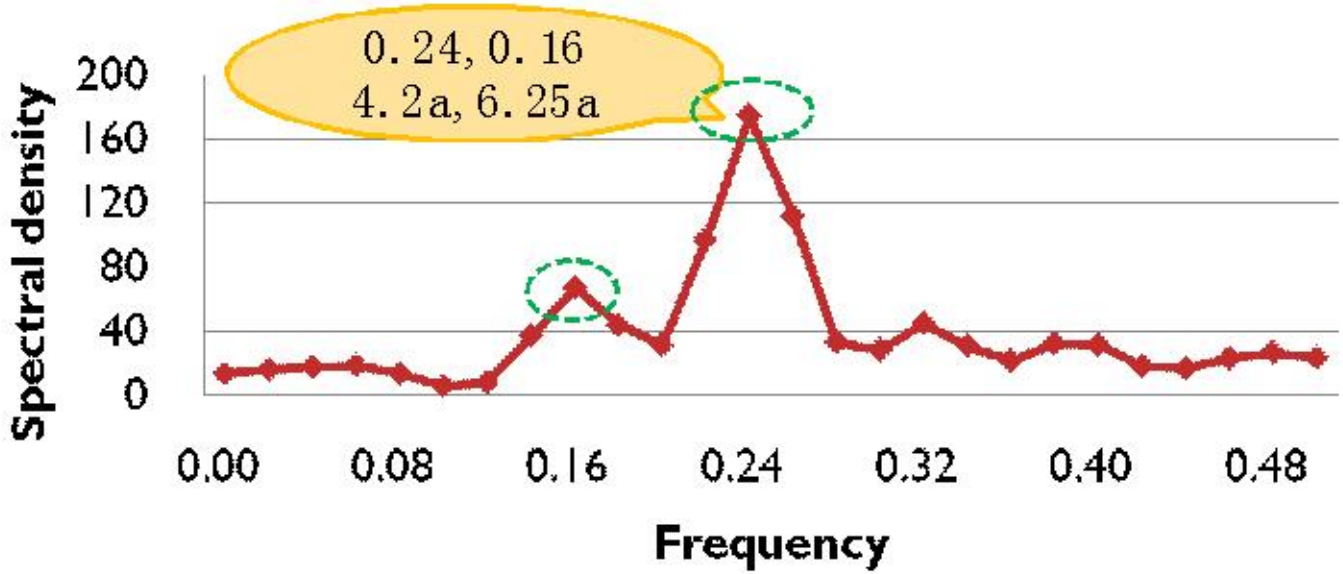
$y = -0.842x + 156.54$, $R^2 = 0.6788$, x is longitude, unit is ° .Y is latitude, unit is ° .



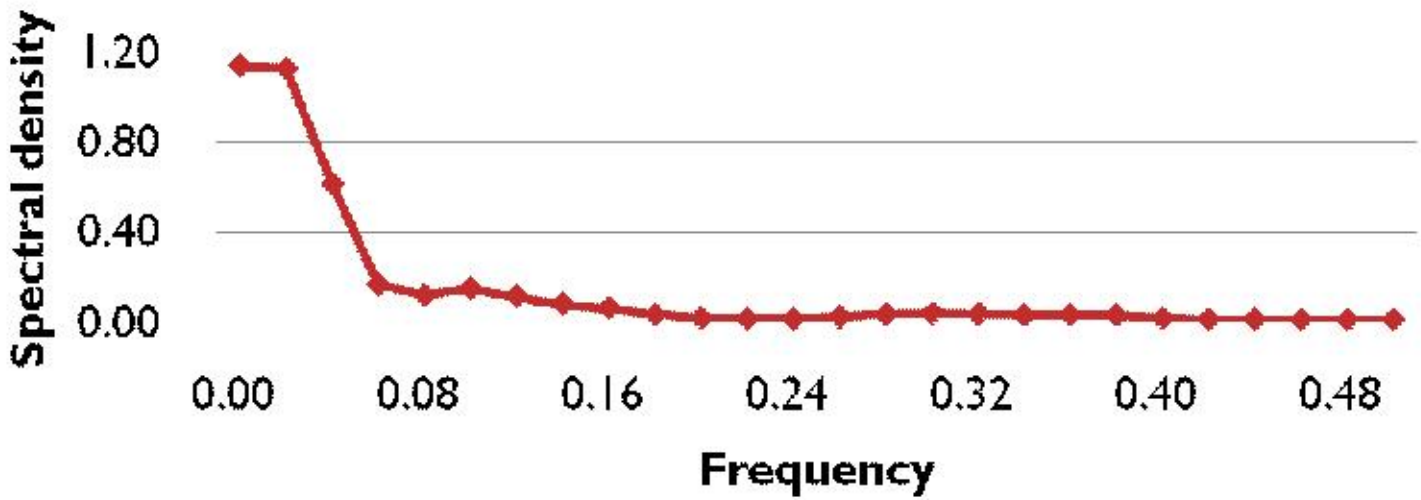
The maximal value of fire movement toward west is 128.68° E, and the least value of fire movement toward east is 123.07° E. In latitude direction, the maximal value towards north is 52.82° N, the least value towards south is 46.86° N.

- Centroids of burned area in Alaska and California move towards low latitude. Centroids of burned area in Alaska have moved 5.94° towards south from 1950 to 2000, and the distance is 457.2km. Centroids of burned area in California have shifted 4.74° towards south from 1895 to 2001, and the distance is 608.0km.
- In California, centroids of burned area move towards east along with fluctuation, besides the impact of regional location, also affected by climate change, fuel management. In Heilongjiang Province, for overmuch human disturbance, the centroids of burned area have obvious fluctuation and with not obvious movement in space.

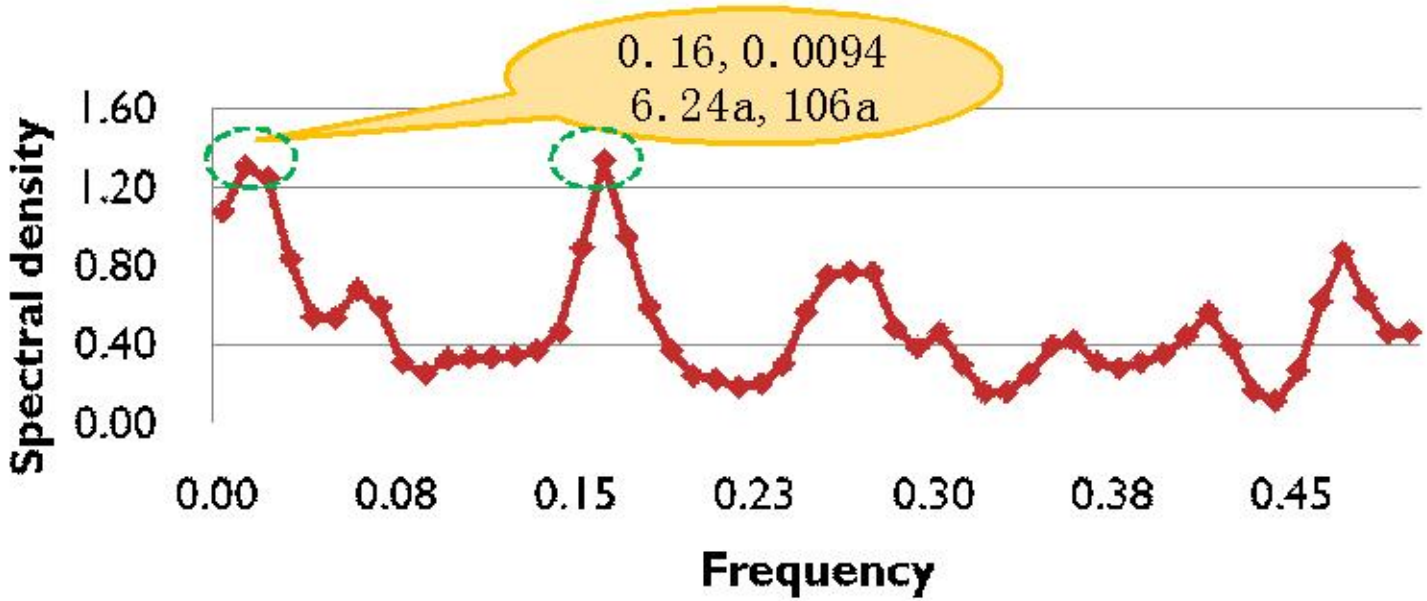
Fluctuation of forest fires in spatial dimension



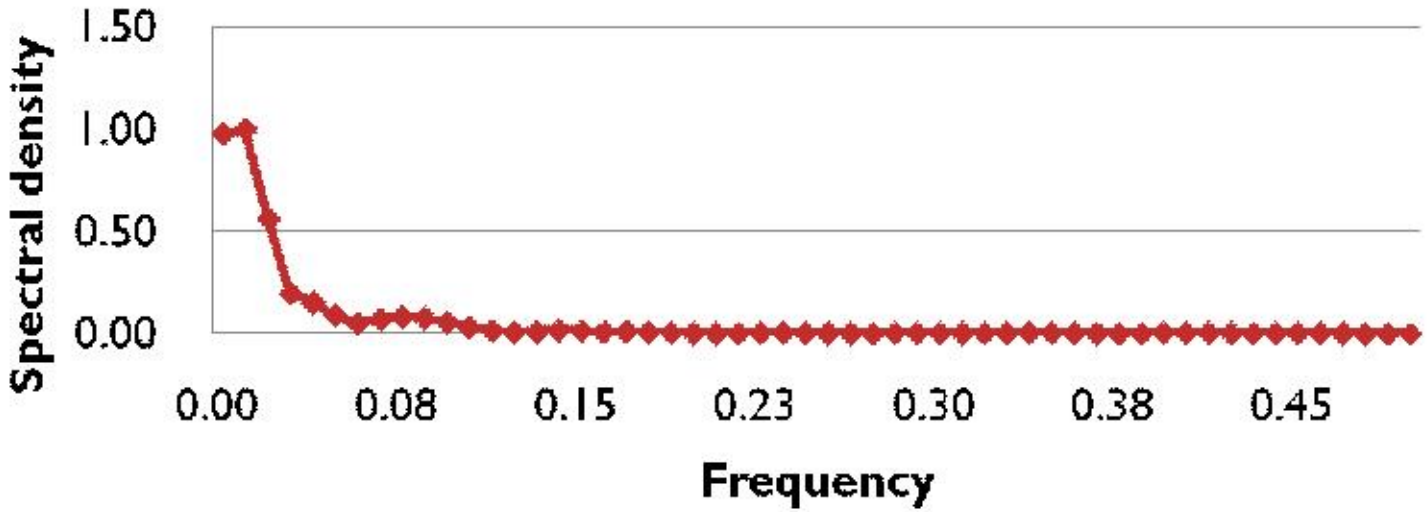
Alaska State, longitude



Alaska State, latitude

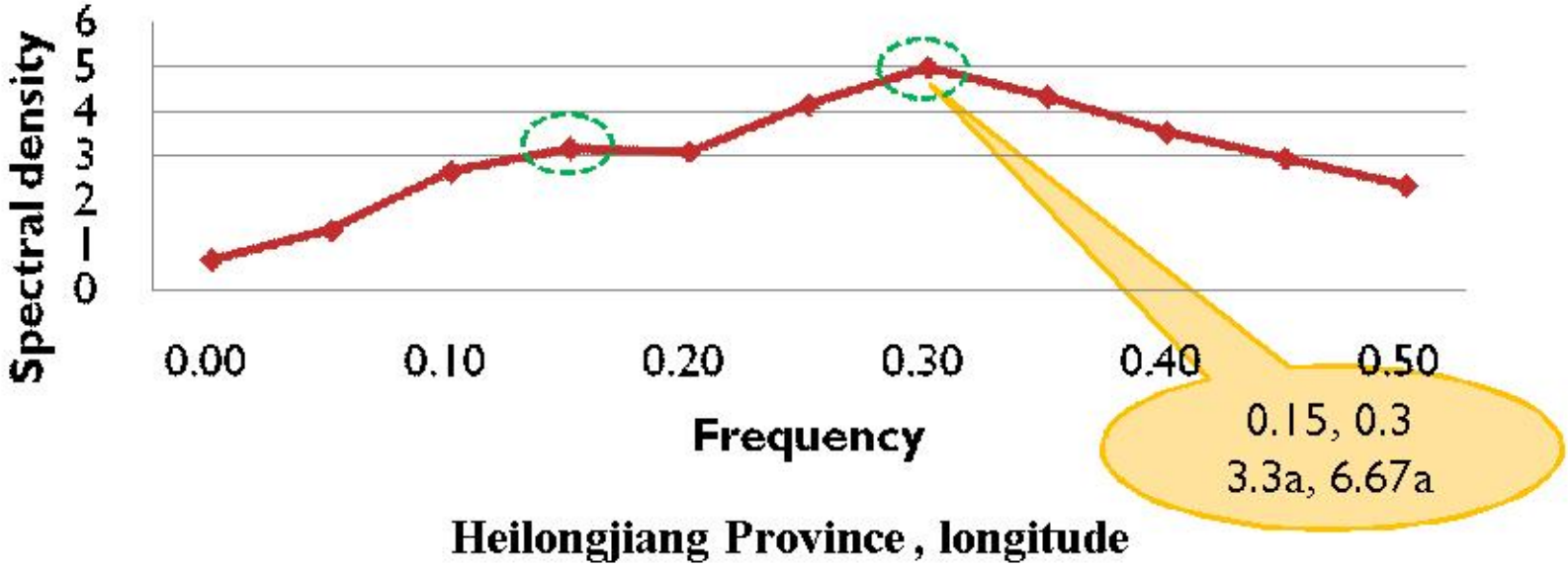


California State, longitude

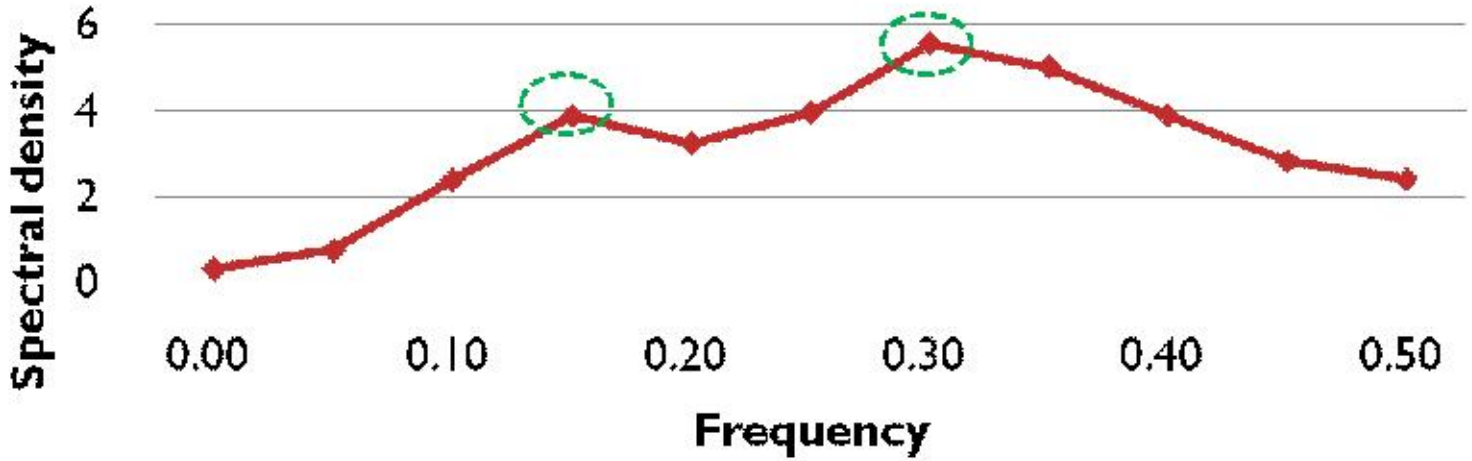


California State, latitude

- There is no periodicity of centroids of burned area in Alaska and California along latitude. We can notice that most of the fires in these two regions concentrate on low frequency; this means that fire intervals are very long, and the intervals are abnormal. These phenomena are related with forest fire management ability. For the high level of fire fighting ability, the burned area is limited under small area level for rapid fighting. Fuel accumulates rapidly for fire exclusion, and fuel energy accumulated is very high. In extreme weather condition, once ignited, the fire is very easy to be out of control, and fighting plays tiny role on fire control. Big fires with different fires interval predominate these two regions. Big fires in California in 2003 are a very typical example of above phenomena.



Heilongjiang Province , longitude



Heilongjiang Province, latitude

- **Periodic fluctuation of forest fires are beneficial to forest health. For those regions with small fluctuation for a long time, forest fires maintain in a low level, these regions are inclined to break up big forest fires. This fact is just consistent with the theory of Self Organized Criticality; periodic fluctuation of forest fires is good for decrease fuel accumulation and fire intensity. Fluctuation is more obvious than movement in longitude direction, but in latitude direction, movement in space is stronger than fluctuation. There are multiple factors that influence forest fires movement in space. Meteorological factors are just some of these influencing factors, other factors, such as forest management, forest fires management, population distribution etc. influence the movement jointly.**

- Fire sources are the leading factors for forest fires occurrence. Distribution of burned area has strong correlation with distribution of fire sources. Fire sources vary with time and space.
- Forest fire number is greatly correlated with population distribution, the nearer to resident the more fires occur. Forest fires near the resident, for convenient traffic, the fires can be control in low level.
- Fire sources are divided into natural fires and anthropologic fires, in northeast of China, lightning fires account for the most proportion of natural fires. The distribution of anthropologic fires is great related to human distribution. Hu and Jin's (2002) study showed that fire number is positive correlated with human distribution in forest region. Burned area has no correlation with human population, natural fires in southeast is more than in northwest in Heilongjiang province. Fire number in the area where developed earlier is more than where developed later. Anthropologic fires are influenced by resident, traffic density, fire sources density, and climate.

- For fire centroids, the size and distribution of burned area determined the distribution of fire centroids. For the continuous accumulation of fuel and rapid release of energy (Drossel and Schwabl, 1992; Song et al., 2001), and other correlated factors, forest fires have the characteristic of fire circle. The periodical accumulation of fuel and annual fluctuation of weather determine that the fire centroids are influenced by weather in short term and influenced by fuel accumulation in long period. So the fluctuation of fire centroids presents different periodicity in temporal dimension.

Discussion

- **We selected three typical regions to study spatial fluctuation of forest fires. In future we will focus more on larger scale and longer period to study how meteorological factors to influence the fluctuation of forest fires. The factors that influence spatial fluctuation of forest fires are variable and complicated, they relate to a serial of stochastic and periodic variables. Multiple factors acting on together lead to stochastic and periodic fluctuation in spatial dimension, we just studied periodic fluctuation in this paper.**
- **For stochastic fluctuation and their related factors, and their meaning under global change background should be studied in the future. Spatial distribution of forest fires is still lack of some quantitative factors to describe it. Meteorological model combined with vegetation distribution, vegetation succession, and vegetation dynamic model, can be used to simulate the regional distribution characteristic of forest fires in the future.**

THANK YOU FOR YOUR ATTENTION!