Analysis of Temporal and Spatial Characteristics of Global Fires

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Abstract. Fires will not only affect the natural environment and human health, but also the satellite sensor for detecting infrared signals because of the strong infrared radiation. Based on statistical methods and visual analysis, this paper analysed the fire product data from 2015 to 2018 provided by the Visible Infrared Imaging Radiometer Suite (VIIRS) to understand the spatial and temporal distribution characteristics of global fires. The research contains the following results: the spatial distribution of global fires is basically the same in different years; The global fires are mainly concentrated between 45°S–75°N latitude zone; The maximum of global fires for four years occurred in August, and minimum in May; The monthly number of fires in different latitude bands has a significant periodicity; The mainly distribution of fires are shifted in the northern and southern hemispheres with seasonal changes. The research results will lay the foundation for studying the distribution and type discrimination of fires.

1. Introduction
Fire is a common phenomenon on the earth, affecting not only the natural environment and human health, but also the performance of infrared detection equipment on the satellite [1]. Fires have a strong infrared radiation, which has a great influence on the system in space that actively detects the infrared radiation and is prone to false alarms [2]. Therefore, research on the spatial and temporal distribution of global fires will help reduce these errors.

Fires are caused by natural factors and human factors. Natural factors are mainly affected by climate and earth activities, such as vegetation burning and volcanic eruptions. And human factors have a strong connection with human activities, such as straw burning and industrial heat discharge.

In this paper, we analyse the global fires based on statistical methods of the four complete years of VIIRS data ranging from 2015 to 2018 and obtain the spatial and temporal characteristics of the global fires. The research results will lay the foundation for fire type discrimination and prediction technology.

2. Data and Methods

2.1. Data Sources
All the fire product data presented in this paper was generated by the Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi National Polar-orbiting Partnership satellites (Suomi NPP). The resolution of the sub-satellite point is up to 375m, so data contained more detailed fire information. Time range of data is from January 1, 2015 to December 31, 2018, the four complete years. The fire product data recorded a total of 80,821,036 fire events and each event contains information such as date, time, latitude and longitude coordinates, etc [3].
2.2. Data Preprocessing

Data pre-processing mainly includes the following three steps: Firstly, delete the records that lack critical information; Secondly, delete redundant information to reduce the size of the data; Thirdly, the nighttimes’ recordings in the range of 11°E~110°W and 7°N~55°S are affected by the magnetic anomalies in the South Atlantic Ocean [4], which may cause the brightness temperature of the mid-wave infrared channel to be too high and misidentified as a fire event, so we delete the nightly records of the area to reduce the impact on the accuracy of the research results.

2.3. Methods

We used two statistical methods to analyse the temporal and spatial characteristics of global fires:

- The surface of the earth is divided into several grids of 0.1°×0.1° by warp and weft, and the number of fires in the grid is counted according to the latitude and longitude coordinates information of the fire event. Then visualize the spatial distribution of the fires by generating a two-dimensional frequency histogram to understand the density of fires in different regions.
- Using the normalization method to analyse the distribution of fires in different months, that is, the proportion of fires in the month to the total number of fires in the year, to understand the changes in the number of fires in each month in different years.

3. Spatial Characteristics Analysis

3.1. Global Spatial Distribution

Figure 1 shows the spatial distribution of global fires from 2015 to 2018, and the depth of the color represents the density of fires in the grid. The result shows that the spatial distribution of global fires in different years is basically the same, thus it can be considered that there is certain regularity in the spatial distribution of global fires.

![Figure 1](image-url)

**Figure 1.** Two-dimensional Frequency Histogram of Global Fire Distributions from 2015 to 2018

Figure 2 shows the histogram of fire distributions at different latitudes in 2018, with an interval of 1°. The results show that the frequency of fires on both sides of the equator is higher, and the fires are mainly concentrated between 45°S and 75°N. The main reason is that there is less land on the 45°S~90°S and 75°N~90°N latitudes, and there are some climatic factors.
Figure 2. Histogram of Fire Distributions at Different Latitudes in 2018 (interval of 1°)

3.2. Spatial Distribution in Continents
The fires have different distribution characteristics in different continents. By analysing the distribution of fires on all continents (excluding Antarctica) in 2018, combined with land cover types to determine the type of fire event. Table 1 shows the global land cover types and description according to the UMD classification scheme [5].

| Type | Description               | Type | Description                  |
|------|---------------------------|------|------------------------------|
| 0    | Water bodies              | 9    | Savannas                     |
| 1    | Evergreen needleleaf forest | 10   | Grasslands                   |
| 2    | Evergreen broadleaf forest | 11   | Permanent wetlands           |
| 3    | Deciduous needleleaf forest | 12   | Croplands                    |
| 4    | Deciduous broadleaf forest | 13   | Urban and built-up lands     |
| 5    | Mixed forests             | 14   | Cropland/natural vegetation mosaics |
| 6    | Closed shrubland          | 15   | Snow and ice                 |
| 7    | Open shrubland            | 16   | Barren                       |
| 8    | Woody savannas            |      |                              |

Table 1. Global Land Cover Types and Descriptions

Figure 3 shows the comparison of global fire distributions and land cover types in 2018. The main land cover types of fire occurrence locations on each continent were obtained through statistics and analysis. The results are shown in Table 2.

| Continent    | Land cover types                                                                 |
|--------------|----------------------------------------------------------------------------------|
| Asia         | Evergreen broadleaf forest, Croplands, Savannas, Cropland/natural vegetation mosaics, Mixed forests, Deciduous needleleaf forest, Barren |
| Europe       | Deciduous broadleaf forest, Croplands, Mixed forests, Cropland/natural vegetation mosaics, Water bodies |
| Africa       | Evergreen broadleaf forest, Woody savannas, Grasslands, Cropland/natural vegetation mosaics |
| North America| Evergreen broadleaf forest, Deciduous broadleaf forest, Woody savannas, Grasslands, Mixed forests, Open shrubland, Croplands |
| South America| Evergreen broadleaf forest, Deciduous broadleaf forest, Savannas, Open shrubland, Grasslands |
| Oceania      | Evergreen broadleaf forest, Woody savannas, Savannas, Open shrubland, Croplands    |
In the Asian continent, fires are concentrated in South, Southeast and Northeast. The main land cover type in the location of the fires in South Asia is croplands. In Southeast Asia, the land cover types are evergreen broadleaf forest and cropland/natural vegetation mosaics. In East Asia, the probability of a fire occurring in mixed forests and croplands is greater. In North Asia, fires occur frequently in mixed forests, savanna and deciduous needleleaf forests due to climatic reasons. In Central Asia and West Asia, the climate is relatively dry, so fires occur mostly in open shrubland, grasslands and barren. In addition, due to the abundant oil resources in Central Asia and West Asia, the combustion of tail gas in industrial facilities such as refineries is the main cause of fires on barren.

In the European continent, the fires are concentrated in the east. The main land cover types in the location of the fires in Europe are deciduous broadleaf forest, croplands, mixed forests and cropland/natural vegetation mosaics. The occurrence of fires in croplands is relatively frequent and the main reason is related to straw combustion. North Sea oil field, located at the sea surface in northwestern...
Europe, is also a concentrated area where fires occur. Tail gas combustion during oil exploitation is the main cause of fires in the area.

As shown in Figure 3, Africa is the continent with the most fires because the climate of Africa is high temperature and less rain, which is extremely prone to fire. The tropical rainforest region is located in central Africa, causing precipitation to decrease from the equator to the north and south. The distribution of fires is concentrated on both sides of the equator and on the island of Madagascar. The main land cover types at the location of the fires in Africa are evergreen broadleaf forest, woody savannas, grasslands and cropland/natural vegetation mosaics.

In the South American continent, fires are concentrated in the northern and central parts of South America, in countries such as Colombia, Venezuela and Brazil. South America has high vegetation coverage. The forest area accounts for more than 50% of the total area of the whole continent and the grassland area accounts for about 25%, which is an important factor that causes a wide range of fires. The main types of land cover at the location of fires in South America are evergreen broadleaf forest, deciduous broadleaf forest, savannas, open shrubland and grasslands.

In the Oceania continent, precipitation decreases from east to west and from the equator to the north and south, leading to a relative concentration of fires in the northern and eastern parts of Australia, southwestern Australia, and the southern part of the Independent State of Papua New Guinea. The main types of land cover at the locations of fires in Oceania are evergreen broadleaf forest, woody savannas, savannas, open shrubland and croplands.

In the North American continent, fires are concentrated in the east, south, and parts of the western and central parts of the United States. The location of fires in the eastern part of North America is mainly deciduous broadleaf forest, woody savannas, grasslands, mixed forests and croplands. In Mexico and Central America, the locations of fires are mainly in evergreen broadleaf forest, woody savannas and open shrubland. In the western and central parts of the United States, evergreen broadleaf forest, grasslands, and croplands are the main types of land cover where fires occur.

4. Temporal Characteristics Analysis

4.1. Monthly Trends of Global Fire Counts

Figure 4 shows the percentage of monthly global fires from 2015 to 2018 by the method mentioned in section 2.3. The monthly trends of global fire counts in different years are basically the same. In terms of time distribution, the probability of global fire occurring is highest in August and lowest in May. The result shows that the occurrence of global fires has a certain temporal characteristic.

![Figure 4. Percentage of monthly Global Fires from 2015 to 2018](image)

4.2. Monthly Trends of Fire Counts in Different Latitude Bands

We analysed the monthly trends of fire counts in different latitude bands from 2015 to 2018. The latitude bands that studied are geographically divided into the tropics (22.5°N~22.5°S) and the extratropics (67.5°N~22.5°N, 22.5°S~ 52.5°S). Figure 5 shows monthly total fire counts within 15° latitude
bands from 2015 to 2018 [6]. A remarkable annual cycle of monthly fire count trends is observable in the figures.

![Figure 5](image1.png)

**Figure 5.** Monthly Total Fire Counts within 15° Latitude Bands from 2015 to 2018

In the tropics, fires occur frequently during the dry season. In the Northern Hemisphere, the high incidence of fire is from November to April of the following year in the 22.5°N~7.5°N latitude band. In the Southern Hemisphere, the number of fire occurrences increased significantly from June to October in 7.5°S~22.5°S latitude band, the maximum occurred in August and September, and the fire counts is largest among all latitude bands. In the equatorial regions, the peaks of fire counts occurred in January and August, which coincided with the dry season in the 7.5°N~7.5°S latitude band.

In the extratropics, fires occur frequently in summer. In the Northern Hemisphere, the peaks occurred in July and August and the troughs occurred from November to March of the following year in the 67.5°N~52.5°N latitude band. In the 52.5°N~37.5°N latitude band, there are two peaks of fire counts in April and August. In the Northern Hemisphere subtropics (37.5°N~22.5°N) a maximum occurred in March and April. In the Southern Hemisphere, the 22.5°S~37.5°S latitude band has a similar change in the number of fires with the 7.5°S~22.5°S latitude band. The land area of 37.5°S~52.5°S latitude band and beyond is small, so there is less fire activity.

### 4.3. Monthly Trends of Global Fire Distributions

Figure 6 shows the monthly trends of global fire distributions in 2018. From December to February, the fires mainly occurred in the northern hemisphere, especially in the African equatorial region of the northern hemisphere. From March to May, the distribution of fires gradually shifted from the northern hemisphere to the southern hemisphere. From June to September, the fires mainly occurred in the southern hemisphere, especially in southern Africa, the subtropical region of South America and the northern part of Australia. From October to December, the distribution of fires gradually shifted back from the southern hemisphere to the northern hemisphere.
Furthermore, some areas in the world have seasonal characteristics. In Eastern Europe, the peak of the fire occurred from April to October. In the northern part of the Asian continent, the fire counts increase significantly from July to September. In North America, the peak of the fire occurred in March and April. Overall, the spatial distribution of global fires has a significant periodicity.

![Maps showing monthly fire distribution](image_url)

**Figure 6.** Monthly Trends of Global Fire Distributions in 2018
5. Conclusions and Discussion
In this paper, we studied the temporal and spatial characteristics of fires on the earth surface based on the global fire product data generated by VIIRS sensor from 2015 to 2018, combined with statistical analysis methods. The conclusions are listed as follows:

• By visualizing the spatial distribution of global fires from 2015 to 2018, the result shows that the spatial distribution of global fires is basically the same in different years, so there is certain regularity.
• By counting the distribution of global fires in different latitudes in 2018, the result shows that the global fires are mainly concentrated between 45°S~75°N latitude zone, because the land area in this latitude zone is less than other latitude zones.
• By normalizing the number of global fires in different months from 2015 to 2018, the result shows that the probability of global fire occurring is highest in August and lowest in May, and the global fire counts in August are more than twice in May.
• By analysing the changes of fire counts in different latitude bands from 2015 to 2018, the result shows that the monthly number of fires in different latitude bands has a significant periodicity.
• By visualizing the monthly spatial distribution of the global fires in 2018, the result shows that the spatial distribution of the global fires has a significant periodicity.

In summary, the global fires have significant temporal and spatial characteristics, making it possible to use artificial intelligence algorithms to predict the distribution of global fires under specific space-time conditions. By matching the land cover types at the location of the fires, it is also possible to achieve automatic discrimination of the type of fire, which is the focus of the next research.

6. References
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