# LATITUDINAL TRENDS OF SMALL-SCALE WILDFIRES IN EASTERN SIBERIA OBSERVED BY LONG-TERM SATELLITE DATA

**O.A. TOMSHIN, V.S. SOLOVYEV**
tomshinoa@gmail.com
*Yu.G. Shafer Institute of Cosmophysical Research and Aeronomy of SB RAS, 31 Lenin Ave., Yakutsk, Republic of Sakha (Yakutia), Russia 677027*

## ABSTRACT

Wildfires seasonal cycle, air temperature anomalies and precipitation in four latitudinal zones of Eastern Siberia are analyzed by multidecadal remote sensing data and CRU TS dataset. Features of latitudinal distribution of small fire patches (0.2-20 ha) are discussed. Trends and correlations between number of small fire patches, air temperature anomalies and precipitation in each latitudinal zone and month of fire season are analyzed. In general, it can be noted that in the northern part of the boreal zone of Eastern Siberia (zones 1, 2) over the past two decades there has been a noticeable increase in wildfire activity in the first half of summer, possibly related to the effects of climate warming. The dynamics of the trends of small-scale fires in the southern part (zones 3, 4) is ambiguous, requiring further research.

## 1. INTRODUCTION

Wildfires are a fundamental environmental process which plays a significant role in Earth natural cycles. Fires affect different aspects of the environment: forest's composition and structure, species diversity, carbon and nitrogen cycle, soil composition and its water regime, etc. One of the major hazards of wildfires is emissions of combustion products that affect physical and chemical processes in the atmosphere and possesses threat to human health[1-4]. Boreal wildfires contribute up to 9% of global carbon emissions from wildfires[5]. Under the conditions of observed climate change, an increase in the number of fires, their area and, correspondingly, the amount of emissions is expected[6]. Model estimations suggest that the increased frequency and severity of fire weather will be most pronounced in the northern boreal region, including Siberia[7-8]. The aim of this study is to analyze current trends in seasonal dynamics of wildfires in Eastern Siberia (ES) utilizing a long-term satellite observational data.

## 2. DATA AND METHODS

Most of the Eastern Siberia (Figure 1a) is covered by boreal forests, annually exposed to wildfires[9-10]. Over the last two decades (2001-2019) almost all parts of Eastern Siberia experienced a rise in mean air temperature during fire season (April-September) due to global warming (Figure 1b). The highest trend is observed beyond the arctic circle (+1.5-2.0°C), while in southern parts of the region temperature rise is lower (<0.5°C). Different climatic and geographical conditions and a variety of vegetation cover types significantly affect fire regime in the region, which is reflected in the uneven distribution of burned areas (BA). To take these factors into account, we divided the territory of ES into 4 latitudinal zones (Figure 1): zone 1 - 65-70°N; zone 2 - 60-65°N; zone 3 - 55-60°N; zone 4 - 50-55°N.

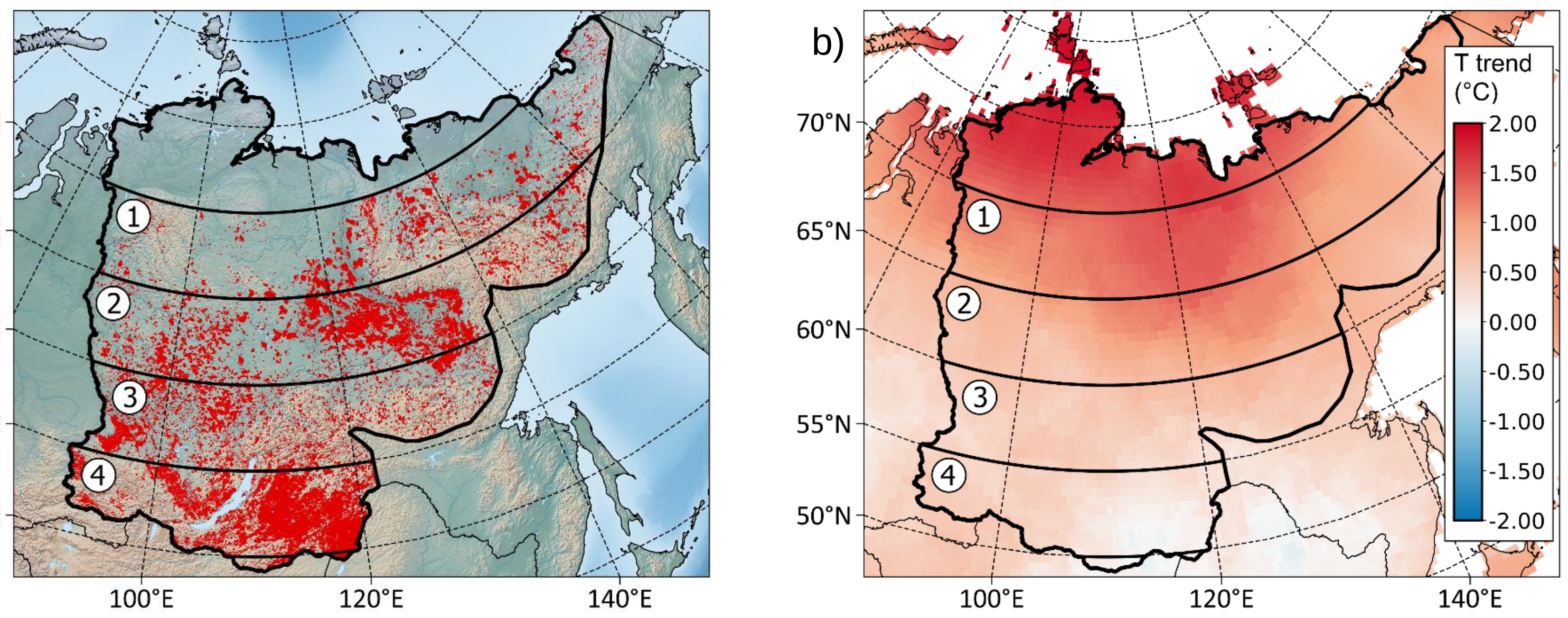


Figure 1. Study area (bold black line) and a) MODIS burned area (MCD64A1 C6, red dots) for 2001-2019, b) trend of mean air temperature (April-September) over 2001-2019 (CRU TS 4.04). The numbers in white circles indicate considered latitudinal zones.

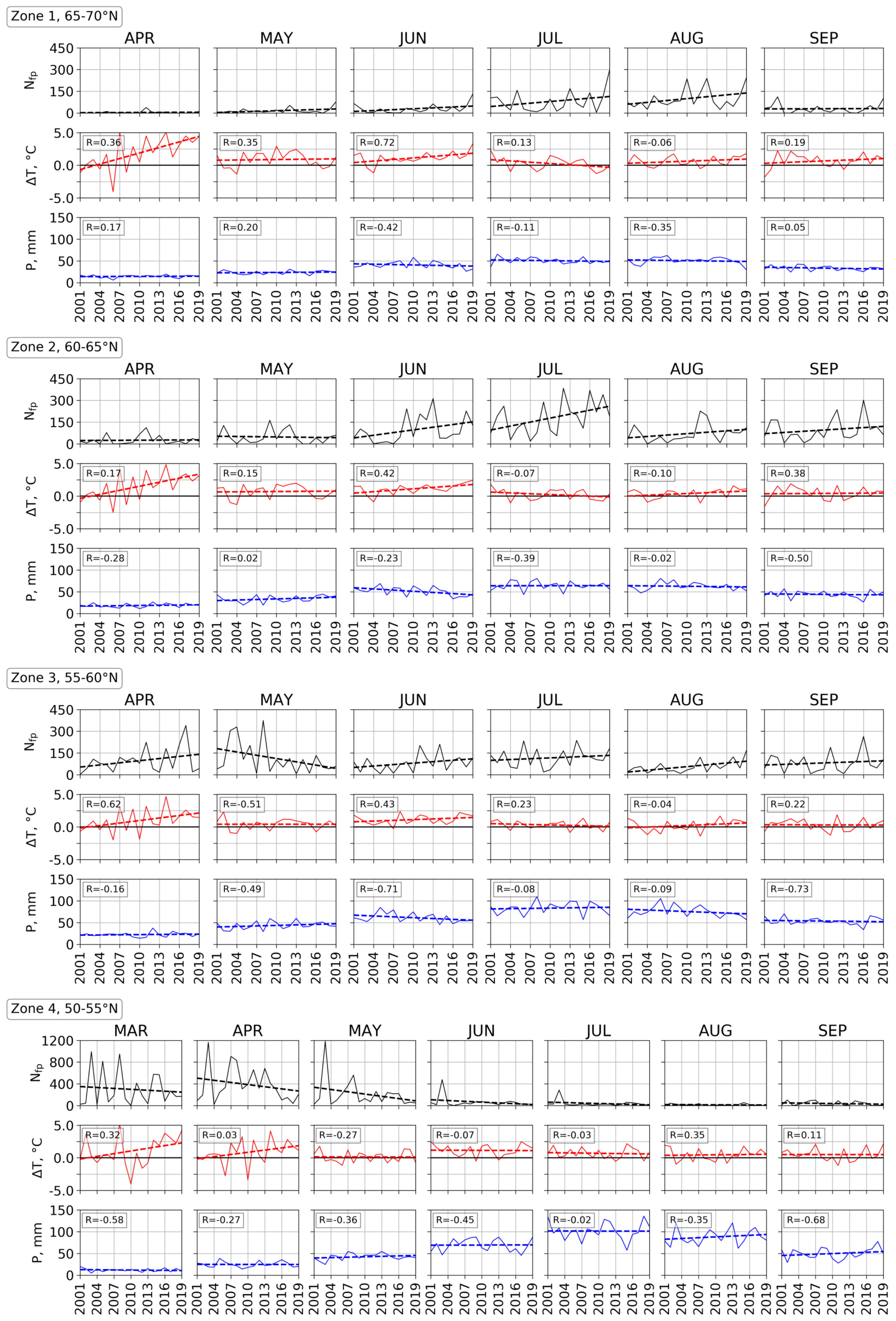
For the analysis of fire activity, we used MODIS product MCD64A1 C6[11] obtained from Terra and Aqua satellites. MCD64A1 C6 is a global monthly burn maps with a spatial resolution of 500 m over the period 2001-2019. Individual burned pixels of the MODIS product were grouped into clusters (fire patches) which then were attributed to an appropriate class based on their area. The paper presents preliminary results of an analysis of the interannual seasonal dynamics of fire patches with areas <40 ha. This class was selected due to better representation of wildfire activity at the initial stage of the fire season and accounts to 40-50% of all fires in the area. For preliminary analysis we decided to evaluate correlation of burnt areas with air temperature anomalies (deviations from 1981-2010 means) and precipitation obtained from Climatic Research Unit gridded Time Series (CRU TS 4.04) dataset[12].

## 3. DISCUSSION

For each latitudinal zone and each month of fire season (April-September for zones 1-3, March-September for zone 4), interannual variations of the total number of fire patches ($N_{fp}$), area mean air temperature anomalies (ΔT) and area mean precipitation (P) were obtained (Figures 2-5). The interannual seasonal dynamics of burns in zone 1 (65-70°N) is presented in Figure 2. The seasonal maximum of $N_{fp}$ usually occurs during July-August and is associated with the later onset of the fire season. There is a positive trend in $N_{fp}$ in June, July and August. High positive trends in temperature are observed in April and June (correlation with $N_{fp}$ R=0.36 and R=0.72, respectively). The increase in $N_{fp}$ in June can be explained by the lengthening of the fire season due to an increase in air temperature in June. Maximum in precipitation usually falls on July-August and don't exceed 60 mm/month. Correlation of $N_{fp}$ and precipitation in this zone is weak, mainly because of low annual amount of precipitation in the area. Low correlation is observed in June (R=-0.42). Precipitation data shows absence of trends in every considered month in this zone.

Figure 3 presents the interannual seasonal dynamics of fire patches in zone 2 (60-65°N). The total number of patches in this zone is quite high, the seasonal maximum is usually observed during June-July with fires stay active through September. High positive trend in $N_{fp}$ is observed in June and July, low - in August and September. A positive trend in temperature is observed in April (R=0.17) and June (R=0.42). Moderate correlation with precipitation is found only in September (R=-0.50), while in other months correlation is weak. Annual amount of precipitation in the zone is relatively low, as in zone 1, and has no significant impact on fire activity. As in zone 1, precipitation data has no distinctive trends.

The interannual seasonal dynamics of fire patches in zone 3 (55-60°N) is presented in Figure 4. $N_{fp}$ shows no distinct seasonal maximum. There is a slight positive trend in $N_{fp}$ in April, June and August, and a negative one in May. In temperature anomalies, a positive trend is observed in April (correlation with $N_{fp}$ - R=0.62), June (R=0.43) and August (R=-0.04), in the remaining months the values are close to long-term mean or slightly higher. High correlation of $N_{fp}$ and ΔT is observed only during the beginning of fire season in the zone, in later months it weakens. Maximum in precipitation occurs in July-August and yields to 110 mm/month, which about 2 times higher, than in zones 1-2. Precipitation have a high impact on $N_{fp}$ in June (R=-0.71) and September (R=-0.73).



Figures 2-5. Interannual variations of $N_{fp}$ (black lines), temperature anomalies (ΔT, red lines) and precipitation (P, blue lines) for each month of fire season of latitudinal zones 1-4. Linear trends are indicated by dashed lines. Correlation coefficients between $N_{fp}$ and ΔT, P are shown in text boxes.

Figure 5 presents interannual seasonal dynamics of fire patches in zone 4 (50-55°N). Fire season in the zone usually starts in March-April, seasonal maximum in fire patches is also usually observed during this period. Fire activity during June-September is relatively low, possibly due to large amounts of precipitation during the period. In March, April and May, a negative trend in $N_{fp}$ is observed. In temperature data, a high positive trend is observed in March and April, in the remaining months the values are close to long-term mean or slightly higher. The correlation of ΔT values and $N_{fp}$ in March and April is low (R=0.32 and R=0.03, respectfully). Precipitation amount in this zone is greater than in all other zones, maximum values in July is usually about 100-125 mm/month. High negative correlation is observed in March (R=-0.58) and September (R=-0.68).

## 4. CONCLUSIONS

A preliminary analysis of the results showed that the seasonal maximum of small-scale fire patches in zone 4 is observed in spring (March-May), in zone 3 there is no pronounced maximum, in zone 2 in June-July, in zone 1 - in July-August. An analysis of trends and correlations of the number of fire patches and temperature anomalies in the northern zone (1) showed the presence of a positive trend in $N_{fp}$ in June, July and August. A positive trend $N_{fp}$ in June is observed along with a positive temperature trend (R=0.72), which may indicate an earlier start of the fire season due to more favorable temperature conditions in the recent years. In zone 2, high positive trends in $N_{fp}$ are observed in June and July. Positive temperature trend in June is also observed (R=0.42), which, as in the case of zone (1), can indicate an earlier start of the fire season. In zone 3, a positive trend in $N_{fp}$ in April, June and August was detected, and a negative trend in May. A positive trend in $N_{fp}$ in April is observed along with an increase in temperature (R=0.62), which may also indicate the formation of more favorable conditions for the early start of the fire season. In zone 4, a negative trend in $N_{fp}$ in March, April and May was detected. A negative trend in March and April is observed despite a positive temperature trend. The correlation between $N_{fp}$ and temperature in March, April and May shows a weak connection (R=0.32, R=0.03 and R=-0.27, respectively). It should be noted that zone 4 has better developed infrastructure and better coverage by air patrols of regional aerial forest protection services. Those factors could possibly contribute to observed reduced number of fire patches in the zone in recent years despite high positive anomalies in air temperature. Analysis of precipitation data showed absence of high trends in all considered zones over a last two decades. Correlation between monthly amount of precipitation and $N_{fp}$ was higher in southern zones (3-4), where total amount of precipitation is higher. In general, it can be noted that in the northern part of the boreal zone of Eastern Siberia (zones 1, 2) over the past two decades there has been a noticeable increase in wildfire activity in the first half of summer, possibly related to the effects of climate warming. The dynamics of the trends of small-scale fires in the southern part (zones 3, 4) is ambiguous, requiring further research.

## REFERENCES

1. Yausheva, E. P., Kozlov, V. S., Panchenko, M. V., Shmargunov, V. P., "Analysis of Black Carbon fraction and aerosol scattering coefficient in smokes of remote forest fires and winter urban smogs," Proc. SPIE 10833, 108334F (2018).
2. Veretennikov, V. V., Men'shchikova, S. S., Uzhegov, V. N., "Variations in Aerosol Microstructure under the Influence of Smokes from Forest Fires according to Inversion of Spectral Extinction Characteristics in the Near-Surface Layer and in Vertical Atmospheric Column," Atmos. Ocean. Opt. 33, 161-171 (2020).
3. Antokhina, O. Yu., Antokhin, P. N., Martynova, Y. V., "Methane emissions from wildfires in Siberia caused by the atmospheric blocking in the summertime," Proc. SPIE 11208, 112086N (2019).
4. Tomshin, O. A., Solovyev, V. S., "The impact of large-scale forest fires on atmospheric aerosol characteristics," International Journal of Remote Sensing 35(15), 5742-5749 (2014).
5. van der Werf, G. R., Randerson, J. T., Giglio, L., Collatz, G. J., Mu, M., Kasibhatla, P. S., Morton, D. C., DeFries, R. S., Jin, Y., van Leeuwen, T. T., "Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009)," Atmos. Chem. Phys. 10, 11707-11735 (2010).
6. Shvidenko, A. Z., Schepaschenko, D. G., "Climate Change and Wildfires in Russia," Contemporary Problems of Ecology 6(7), 683-692 (2013).
7. Flannigan, M., Cantin, A. S., de Groot, W. J., Wotton, M., Newbery, A., Gowman, L. M., "Global wildland fire season severity in the 21st century," Forest Ecology and Management 294, 54-61 (2013).
8. de Groot, W. J., Flannigan, M. D., Cantin, A. S., "Climate change impacts on future boreal fire regimes," Forest Ecology and Management 294, 35-44 (2013).
9. Tomshin, O. A., Solovyev, V. S., "Generating a long-term data series of burned area in Eastern Siberia using LTDR data (1984–2016)," Remote Sensing Letters 10(10), 1008-1017 (2019).
10. Kirillina, K., Shvetsov, E. G., Protopopova, V. V., Thiesmeyer, L., Yan, W., "Consideration of anthropogenic factors in boreal forest fire regime changes during rapid socio-economic development: case study of forestry districts with increasing burnt area in the Sakha Republic, Russia," Environmental Research Letters 15(3), 035009 (2020).
11. Giglio, L., Boschetti, L., Roy, D. P., Humber, M. L., Justice, C. O., "The Collection 6 MODIS burned area mapping algorithm and product," Remote Sensing of Environment 217, 72-85 (2018).
12. Harris, I., Osborn, T. J., Jones, P., Lister, D., "Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset," Sci. Data 7, 109 (2020).