3rd International Electronic Conference on Water Sciences (ECWS-3)
15-30 November 2018

Response of Siberian rivers discharge to disturbance of the forests caused by wildfires

Evgenii I. Ponomarev [1,2,3,*], Tatiana V. Ponomareva [1,3]

1. V.N. Sukachev Institute of Forest SB RAS, Krasnoyarsk 660036, Russia; evg@ksc.krasn.ru
2. Federal Research Center "Krasnoyarsk Science Center, SB RAS", Krasnoyarsk 660036, Russia;
3. Siberian Federal University, Krasnoyarsk 660041, Russia; bashkova_t@mail.ru

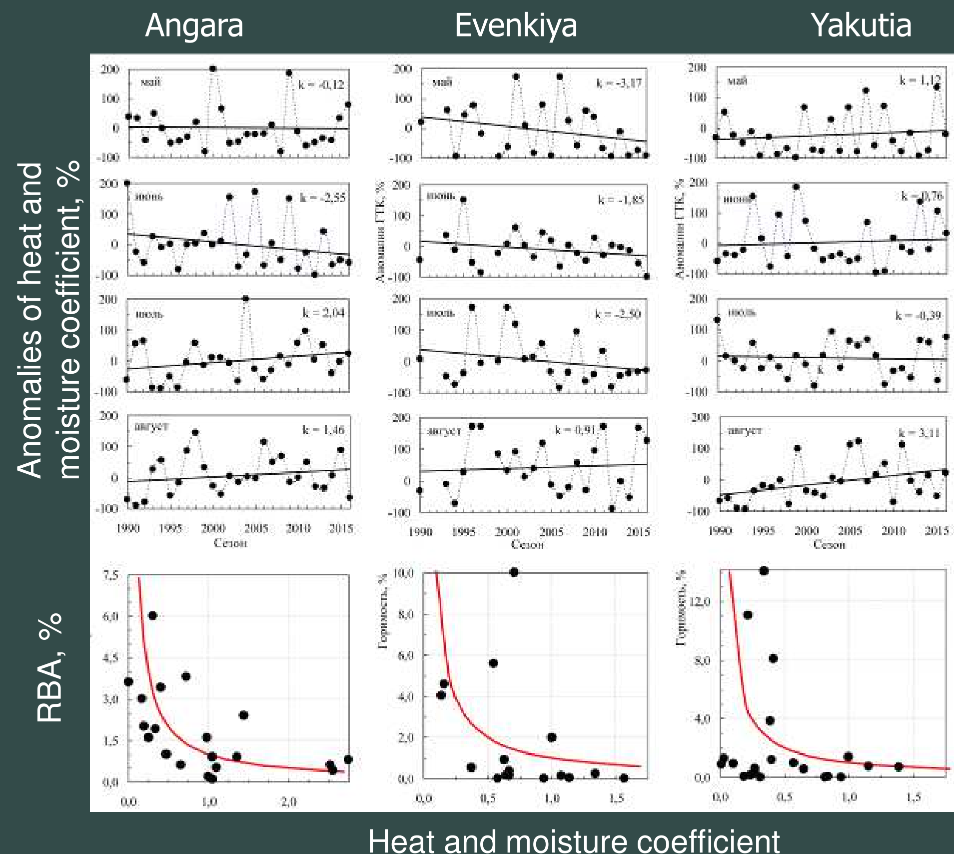
* Correspondence: evg@ksc.krasn.ru; Tel.: +7-391-249-4092

This research was funded by Russian Foundation for Basic Research grant number 17-04-00589 and Government of the Krasnoyarsk krai, and Krasnoyarsk krai Foundation for Research and Development Support, grant number 18-41-242003.
Rivers discharge data was provided by The Global Runoff Data Centre, 56068 Koblenz, Germany.

Wildfires of Siberia under climate change

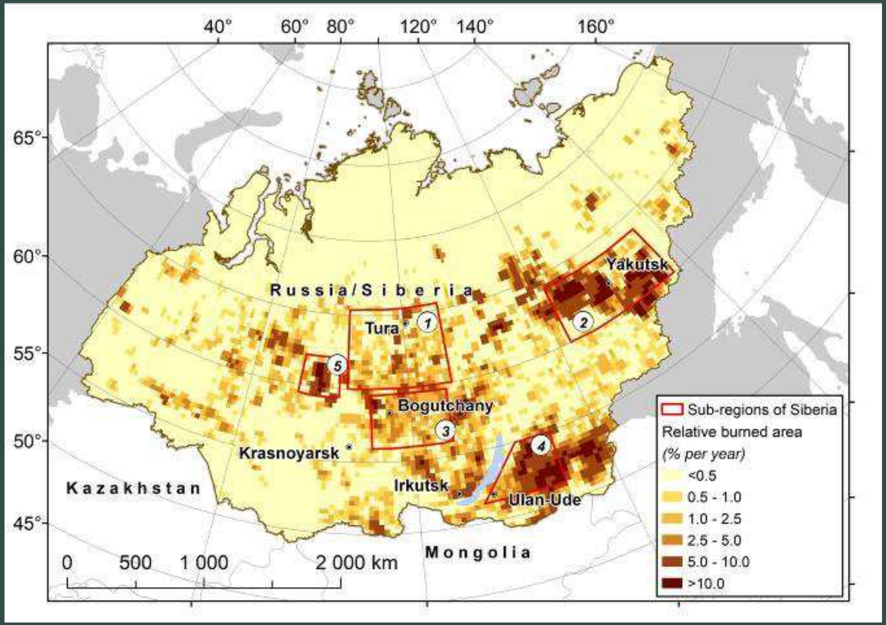
In Siberia, significant and long-term post-fire effects are observed in the permafrost zone, in particular, changes and degradation of the near-surface layers of permafrost, short-term and long-term anomalies of the temperature and water balance. This affects the flow regime of small and medium rivers of Siberia, supplies of which are determined by groundwater (10–25% of total).

In this work, we determined the degree of connection between intra- and interseasonal variations in river runoff with the relative burned area (RBA) of forests in the river basins of Siberia.

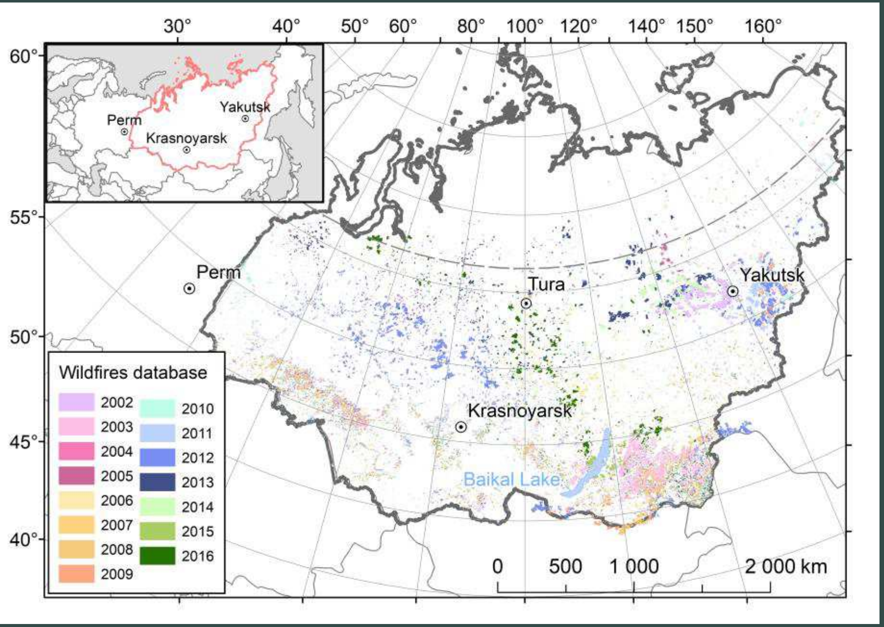


Heat and moisture supply (*top*) trends *vs* RBA (*bottom*) for sub-regions of Eastern Siberia

Fire impact on ground cover / relative burned area



Relative burned area (RBA) per year, %
1 – Evenkiya, 2 – Yakutiya,
3 – Angara river basin, 4 – Trans-Bailkal, 5 – Western Siberia area



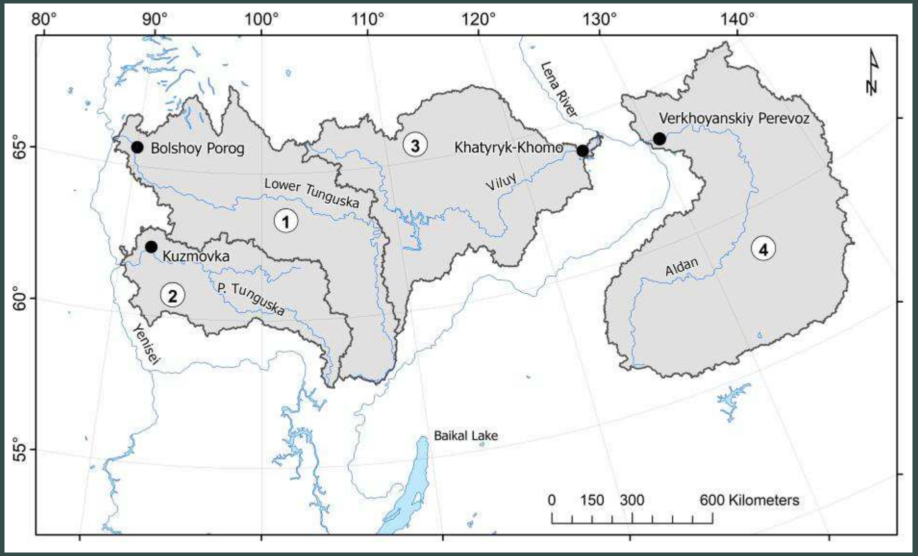
Long-term fire statistics over Siberia for 2002-2016

Relative burned area per year is in range of **0.1% — 14.5%**
Averaged for Siberia — **1.19**%, for western Canada — **0.56**% (*deGroot et al., 2013*).

Area of interest

Examples of post-fire changes in soil and vegetation cover

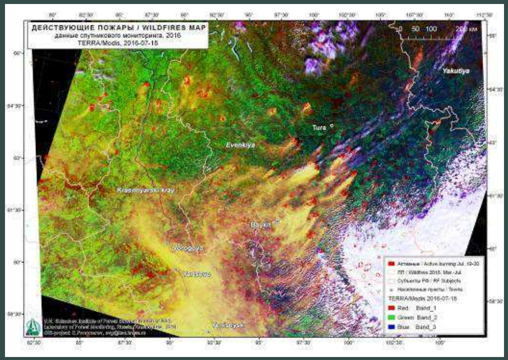
River basins and hydrological points for data collection. River basins are: 1 – Lower Tunguska, 2 - Podkamennaya Tunguska, 3 - Viluy, 4 - Aldan.

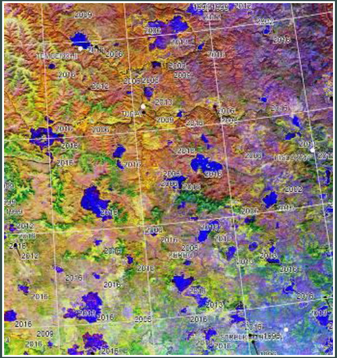


The area of interest is the territory of Siberia within the boundaries of 57–67 N, 85–110 E. The total area is more than 110 million hectares. The studies were performed for four river basins of Central Siberia and Yakutia: Tunguska, Podkamennaya Tunguska (Basin District of Yenisei River), and Aldan, Viluy (Basin District of Lena River).

Satellite remote sensing data used

A Raw satellite data



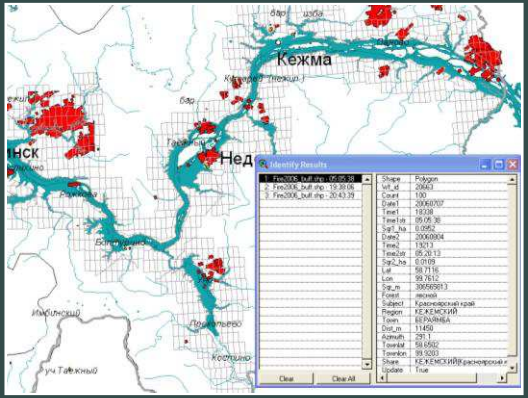


Active burning and post-fire pattern of territory.
Terra/MODIS. 2016, 2017

Terra/MODIS 2017 | **Landsat-8/OLI** 2017 | **Sentinel-2** 2016

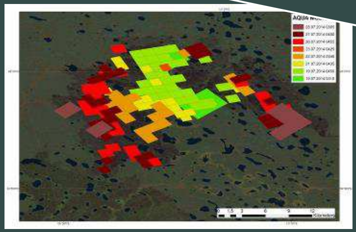
B Pre-processing

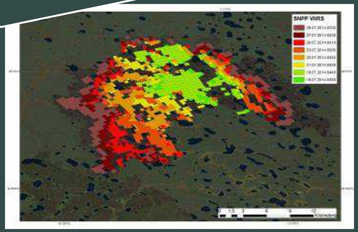
C Wildfire GIS database



Database time: 1996–2018;
Data volume: ~2×10^6 records;
Data format: polygonal GIS layers, and joint attribute information for each record

D Analysis





AQUA/Modis | **SNPP/VIIRS**

Materials and Methods

The long-term data on the flow rate (m^3/s) and river discharge (km^3) was compiled from
the open database R-ArcticNET 4.0 (http://www.R-ArcticNET.sr.unh.edu),
an integrated monitoring system Arctic-RIMS (Rapid Integrated Monitoring System) (http://rims.unh.edu/index.shtml),
The Global Runoff Data Center (http://www.bafg.de),
Composite Runoff Field V 1.0 (http: //www.compositerunoff.sr.unh.edu/).

We analyzed the monthly average water runoff for 1936–2015 at the following hydrological posts: Bolshoy Porog (basin of Lower Tunguska), Kuzmovka (basin of Podkamennaya Tunguska), Khatyryk-Khomo (basin of Vilyui River), Verkhoyanskiy Perevoz (basin of Aldan River).

We determined the average annual value of the discharge (RD_i) and analyzed deviations (RD_i^*) from the average statistical norm (discharge anomalies) for each month (*i*) as

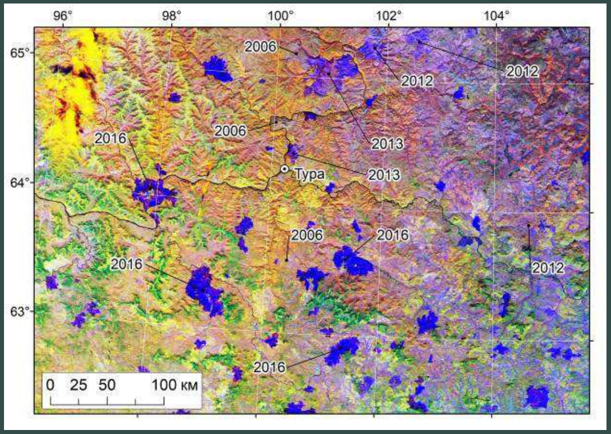
$$RD_i^* = \frac{(RD_i - RD_i)}{RD_i} \times 100\%$$

Next we determined the relative burned area (RBA) of forests within the river basins on the basis of satellite fire monitoring data of the Sukachev Institute of Forest (Federal Research Center KSC SB RAS, Krasnoyarsk, Russia) for 1996–2015. RBA (γ) was defined for each month, as the ratio of the total area of fires (S_{burned}) to the total area of the river basin (S).

$$\gamma = \frac{\sum S_{burned}}{S} \times 100\%$$

Results

In some seasons, we fixed the level of runoff at 68–78% of the average annual rate. While analyzing the available chronologies of extreme fire events in Central and Eastern Siberia, it became possible to compare the discharge minima with extreme fire events.
The frequency of extremely low runoffs, ranging from 18 to 25 years, is consistent with the reported data on the variability of the width of the tree rings in larch forests of Central Siberia, which is determined by the temperature and the moisture regimes of weather. Thus, the phase coincidence of the flow anomalies and extreme fire events associated with the precipitation deficit is defined as was expected.

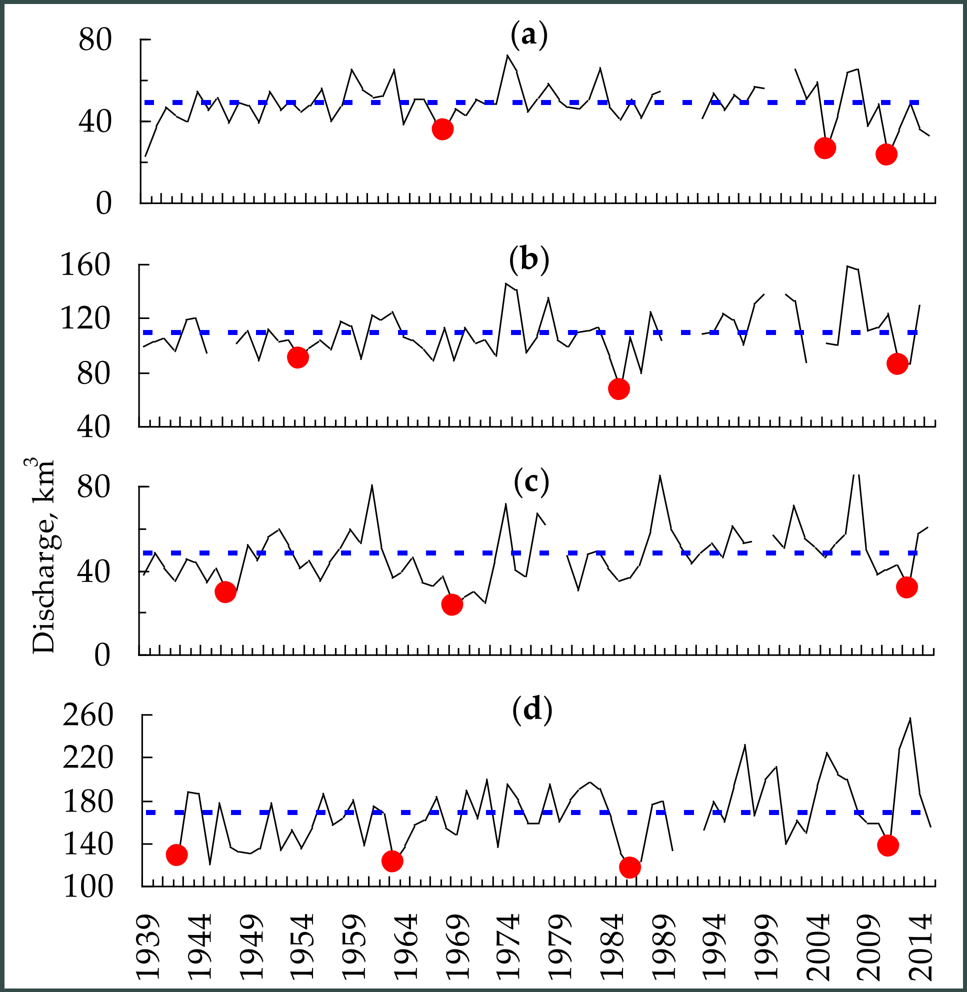


Post-fire pattern

Table 1. Long-term mean of discharge anomalies and RBA ($\gamma_{mean} \pm \sigma$, γ_{max}) for the river basin territories.

River	Area of basin, mln ha	Discharge, km^3	Discharge anomaly, %		γ, %		
			min	max	mean	max	σ
Lower Tunguska	45.6	108.25	–22	29	0.49	2.99	0.60
Podkamennaya Tunguska	23.8	49.87	–21	40	0.51	4.12	0.65
Vilyui	45.5	47.97	–32	36	0.76	6.13	1.15
Aldan	72.8	173.59	–28	32	0.67	5.21	0.77

Fire Chronology data and fluvial discharge



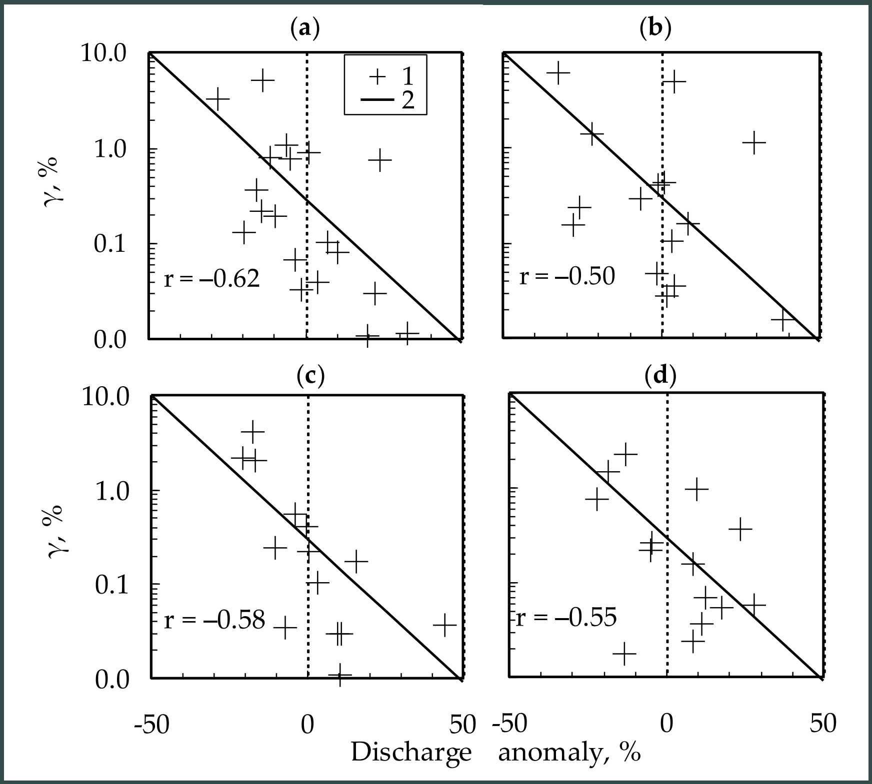
Long-term data on total annual runoff (km^3).

The dots indicate the minima corresponding to the dates of extreme fire events.

Dotted line stands for annual mean value.

River basins: (a) Podkamennaya Tunguska; (b) Lower Tunguska; (c) Viluy; (d) Aldan.

Correlation analysis



Solving the problem of quantitative description of the relationship, we jointly analyzed data on the forest fire in the borders of river basins (γ,%) and runoff anomalies for the first half of the growing season (March – July) for 2002–2015.

The results of the correlation analysis of the relationship between the intraseasonal dynamics of the discharge and the RBA are presented in (Table 2).

Correlation field for RBA within the river basins (γ,%) and discharge anomalies for the first half of the vegetation season (March – July) for the rivers of Yakutia: Aldan (a), Vilyui (b) and Central Siberia: Podkamennaya Tunguska (c), Lower Tunguska (g).
1 – experimental data, 2 – linear model.

Correlation analysis

Table 2. Correlation between discharge anomalies and RBA during the season.

River	Correlation during the season			
	November–February	March–April	May–July	August–October
Lower Tunguska	–0.43	–0.25	–0.83	–0.77
Podkamennaya Tunguska	–0.20	–0.24	–0.66	–0.57
Vilyui	–0.22	–0.16	–0.42	–0.42
Aldan	–0.21	–0.10	–0.47	–0.22

The response to the fire impact was recorded for the territories of the considered river basins of Central Siberia, expressed in an abnormal low discharge during the post-fire summer-autumn period ($r > -0.55$). At the same time, the level of correlation is lower for river basins in Eastern Siberia/Yakutia ($r < -0.45$).

The revealed differences can be a consequence of the post-fire conditions of permafrost soils, which determine the share of groundwater in the formation of the total river flow. Post-fire transformation of vegetation and on-ground cover can be the cause of heat and water balance anomalies as well as changes in the depth of seasonally thawed layer of soils and changes in water permeability of soil horizons. Thus, if we do not take into account seasonal variations in the precipitation regime, then the features of the post-fire discharge anomalies are determined by condition of the system “fire effect” – “ground cover and vegetation” – “soil”. The influence of wildfires is significant only for the seasonally thawed layer which is characteristic of the summer-autumn period.

Conclusion

For the current river basins the scale of wildfire impact is up to 2.5–6.1% of the total area per year. It effects strong on forest ecosystems of the permafrost zone.

Within the river basins of Central Siberia, the response to pyrogenic (post-fire) impact is expressed in anomalies of discharge in the post-fire summer-autumn period (r >–0.52). For river basins in Eastern Siberia, the correlation is less.

The level of significance is determined highly likely by the state and post-fire changes in the permafrost soil conditions.

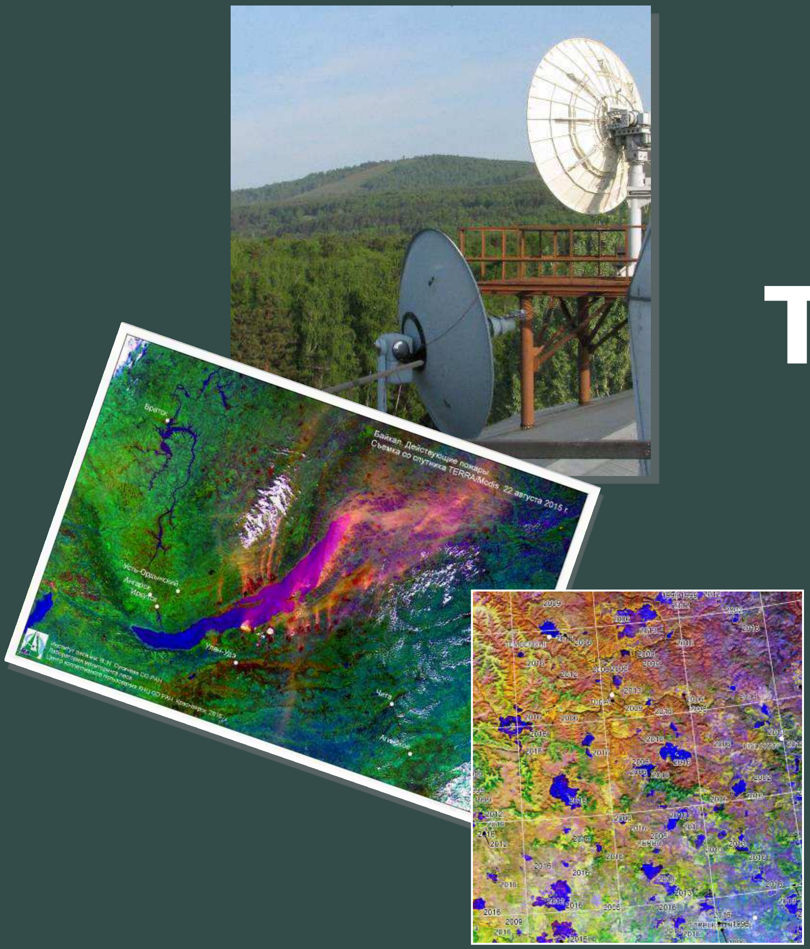
Additional publications:

Ponomarev E.I., Kharuk V.I. (2016) Wildfire Occurrence in Forests of the Altai–Sayan Region under Current Climate Changes // Contemporary Problems of Ecology. 2016. Vol. 9. № 1. P. 29–36. doi: 10.1134/S199542551601011X

Kharuk V.I., Ponomarev E.I. (2017) Spatiotemporal Characteristics of Wildfire Frequency and Relative Area Burned in Larch-dominated Forests of Central Siberia // Russian Journal of Ecology. Vol. 48, No 6, p. 507–512. doi: 10.1134/S1067413617060042

Ponomarev E.I., Skorobogatova A.S., Ponomareva T.V. (2018) Wildfire Occurrence in Siberia and Seasonal Variations in Heat and Moisture Supply // Russian Meteorology and Hydrology. Vol. 43, No. 7, p. 456–463. doi: 10.3103/S1068373918070051.

Ponomarev E.I., Ponomareva T.V. (2018) The Effect of Postfire Temperature Anomalies on Seasonal Soil Thawing in the Permafrost Zone of Central Siberia Evaluated Using Remote Data// Contemporary Problems of Ecology. 2018. Vol. 11. # 4. P. 420–427. doi: 10.1134/S1995425518040066.



Thank you!

Response of Siberian rivers discharge to disturbance of the forests caused by wildfires

Evgenii I. Ponomarev
Tatiana V. Ponomareva