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Thesis abstract

Long-term changes of wildfire regimes in eastern Siberia: an evaluation based on lake sediment indicators and individual-based modeling

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Recent intense wildfire seasons in the circumpolar boreal forests raise questions regarding drivers and impacts of past fire regime changes. Charcoal in lake sediments is commonly used to reconstruct past trends of biomass burning. However, eastern Siberia is poorly covered by such data. Considering the unique larch-dominated forests and their climate-sensitive relationships with permafrost and fire, both affected by ongoing climatic warming, this lack of data presents a key research gap.

By applying both paleo-ecological and modeling methods, this dissertation evaluates (I) wildfire dynamics of the past ca. 20 000 years, (II) relationships between fire regime changes and larch forest structure, and (III) the potential human dimension of past fire regime changes in the Republic of Sakha (Yakutia).

Study sites are located in southwestern Yakutia (Lake Khamra; Glückler et al., 2021) and the western region of central Yakutia (Lake Satagay; Glückler et al., 2022, 2024) and are spread across the Lena–Amga interfluve, the southern Verkhoyansk Mountains, and the Oymyakon Highlands (nine lakes; Glückler et al., 2025).

The highly resolved charcoal record at Lake Khamra, an intermontane basin lake (Baisheva et al., 2024), permits the identification of a mean fire return interval of 43 years throughout the last 2 millennia (Fig. 1). Trends in the charcoal accumulation rate are compared to information on climate, vegetation, and the history of human activity. Palynological data indicate stable vegetation composition throughout the record, pointing towards climatic and/or human drivers of changing fire activity. High amounts of biomass burning around 1000 BP and a following decrease to low levels may correspond to a transition from the Medieval Climatic Anomaly to the Little Ice Age. Both increasing fire activity since the 18th century and a decrease in the 20th century may be related to cultural changes following the colonization of Yakutia by the Russians in the 17th century (Glückler et al., 2021).

At Lake Satagay, a late-stage thermokarst lake (Baisheva et al., 2023), the Holocene charcoal record displays a pronounced maximum at ca. 10 000 BP and suggests the establishment of the modern (preindustrial) fire regime around 4500 BP. Combination with data on terrestrial plants from sedimentary ancient DNA and quantitative vegetation cover based on a pollen record highlights a potential relationship

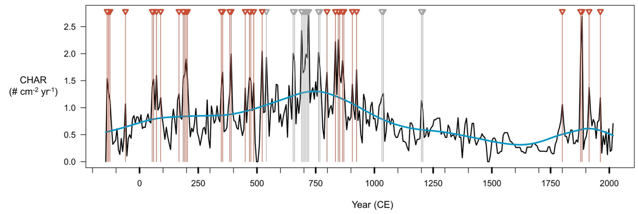

Figure 1. Charcoal accumulation rate (CHAR) throughout the past 2 millennia at Lake Khamra, eastern Siberia. The blue line is a locally estimated scatterplot smoothing (LOESS), whereas red and grey vertical lines indicate statistically identified fire episodes (red and grey colors mark strong or weak separation, respectively, according to a signal-to-noise index). Modified after Glückler et al. (2021).

between open woodlands and a severe fire regime in the Early Holocene. In contrast, dense forests of the Late Holocene may be related to the modern, low-intensity surface fire regime. Based on these findings, it is suggested that thinning forests with continued climate change may result in a positive feedback on intensifying fire regimes (Glückler et al., 2022).

For an analysis of long-term fire–vegetation relationships, the individual-based, spatially explicit forest model LAVESI (*Larix* Vegetation Simulator; Kruse et al., 2016) is expanded with a new fire module and applied to simulate forest development and climate-driven wildfires over the past ca. 20 000 years. Simulations identify diverse impacts of fire regime changes on forest structure and composition. For example, medium-intensity fires at return intervals of 50 or more years are found to stabilize larch dominance, whereas high-intensity, stand-replacing fires rather tend to facilitate establishment of evergreen conifers (Glückler et al., 2024).

Finally, the dissertation comprises a manuscript in preparation that combines paleo-ecological and modeling approaches. Nine new charcoal records from central and eastern Yakutia are combined with existing data to create a composite curve of regional biomass burning in the Holocene. Simulations of climate-driven wildfires and forest development in LAVESI reproduce reconstructed trends in the Early to Mid-Holocene but fail to do so in the Late Holocene. This may hint at a potential human dimension, especially considering that a major cultural shift from nomadic hunter-gatherers and reindeer herders to the more sedentary Sakha cattle and horse breeders occurred during that time. Historical accounts further reinforce the suggested role of indigenous land use and cultural burning practices that may have reduced wildfire severity around settlements (Glückler et al., 2025).

This dissertation provides insights into past wildfire dynamics and their relationships with climate, vegetation, and human activity in a region that was previously poorly studied and will be confronted by continued environmental and climatic changes.

Data availability. Data and code from this dissertation can be obtained as outlined within the included published manuscripts: https://doi.org/10.5194/bg-18-4185-2021, https://doi.org/10.3389/fevo.2022.962906, and https://doi.org/10.1186/s42408-023-00238-8 (Glückler et al., 2021, 2022, 2024).

Competing interests. The author has declared that there are no competing interests.

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