Increased winter runoff in Siberia modeled with tree rings as evidence for the recent high rate of permafrost degradation

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Abstract

The instrumental data shows 7%-20% increase in annual discharge of the major Eurasian rivers like Ob, Yenisei and Lena between 1936 and 2018 (Wang et al. 2021). The trend has been attributed to increased precipitation and permafrost thawing due to the temperature warming (Walvoord, Kurylyk 2016). However, the instrumental data does not provide the longterm scope of the trend. We modeled seasonal discharge from tree rings for the Yenisei River upstream at Kyzyl gauge and found a remarkable 80% upsurge in winter 'ow (Nov-Apr) over the last 25 years, which is unprecedented in the last 214 years since 1784 (Panyushkina et al. 2021). In contrast, the annual discharge (Oct-Sept) has only a 7% increase over the last 25 years and shows normal range of variability since 1700 (Fig. 1). Water balance modeling with CRU data at the Yenisei upstream indicates a significant discrepancy between decadal variability of the gauged 'ow and climate data after 1960 (Fig. 1). The long-term buckhound of the changes in regional hydrology is successfully assessed with tree-ring methods. The tree-ring networks in Eurasian cold climates have a great potential to reconstruct spatial pattern of the seasonal runoff and quantify the long-term impact of permafrost degradation on the hydrological regimes in Siberia. We discuss the impact of melting permafrost on the base 'ow and enrichment of the surface and groundwater interaction at the Yenisei River basin coupled with the warming temperature and, more importantly, forest fires. Recent increase in the frequency, size, and intensity of boreal fires scale s of its impact on hydrology and permafrost in Siberia. This study demonstrates the complexity of hydrological feedback in Siberia to the Arctic Ampli:cation (AA). The adverse impacts of AA have been and will remain the greatest for the health and socioeconomic of people living in the Pan-Arctic and the geopolitics and macroeconomics of the global society.

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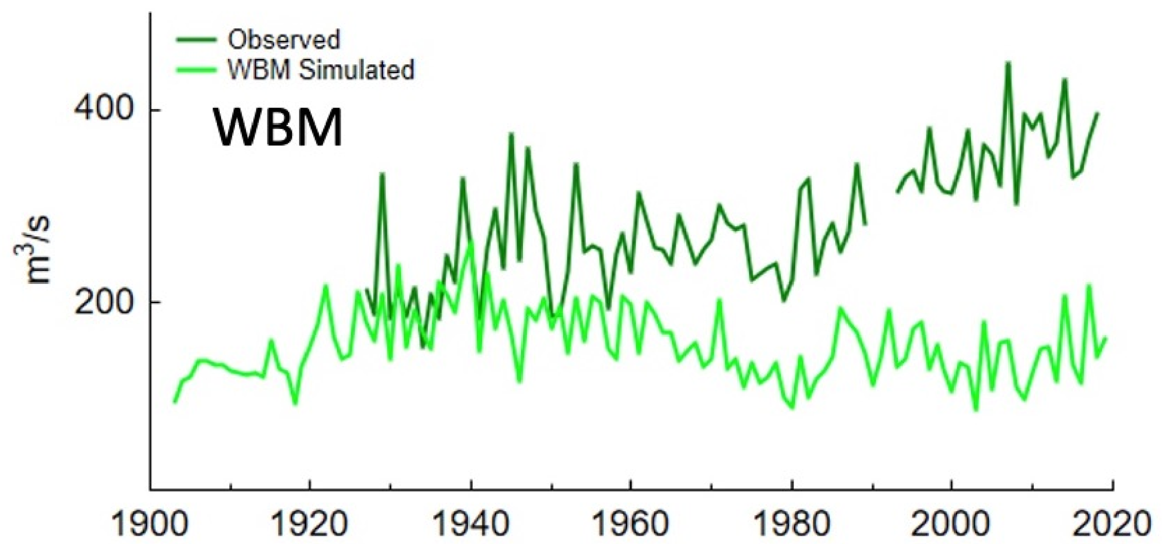
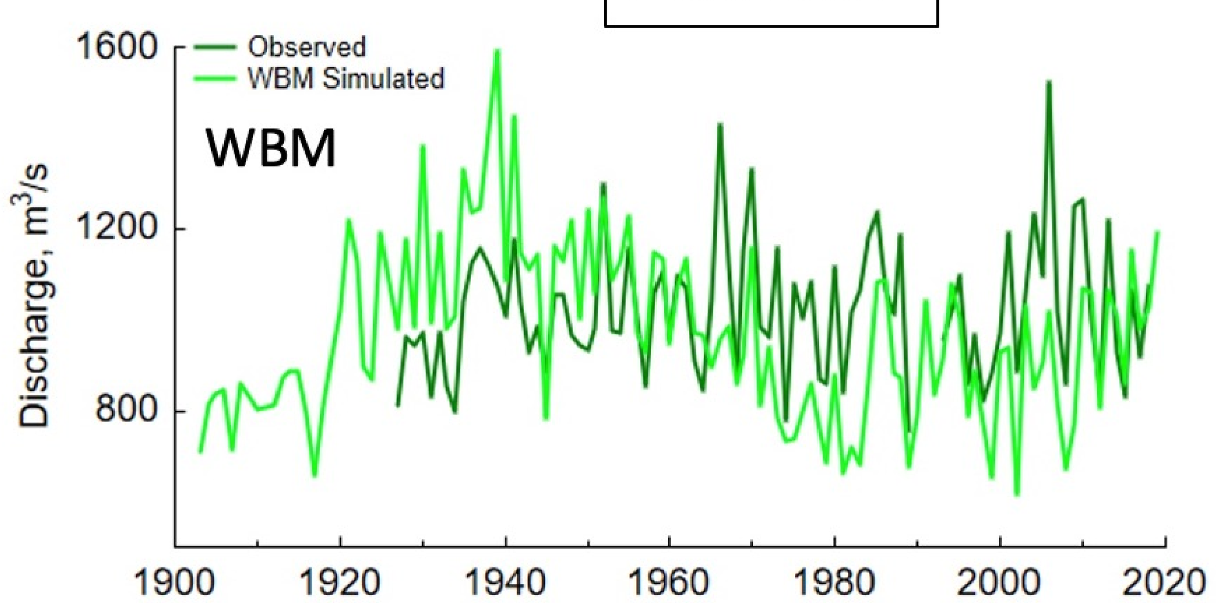
Modeled Discharge of the Yenisei River

Winter

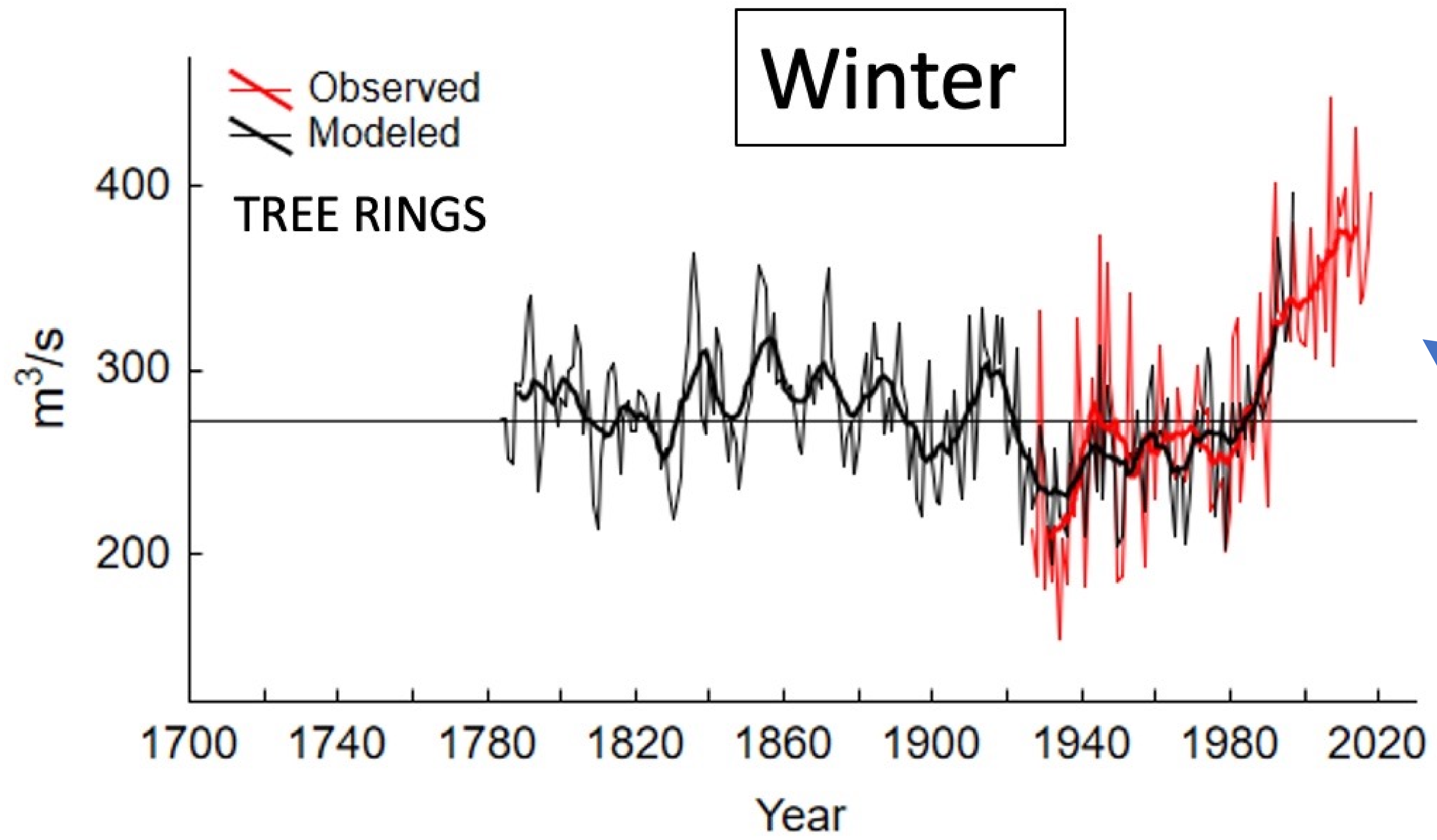


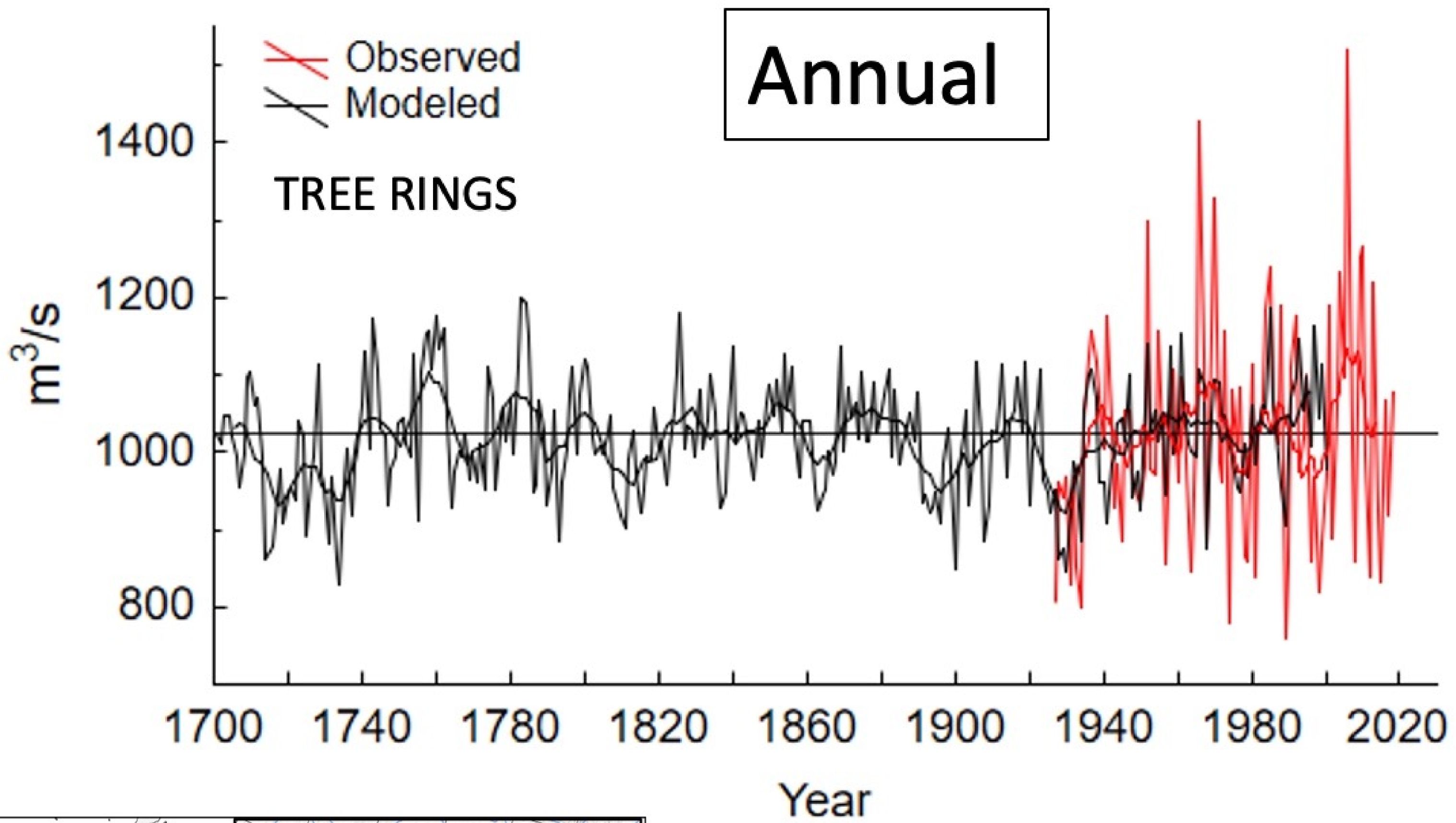
Annual

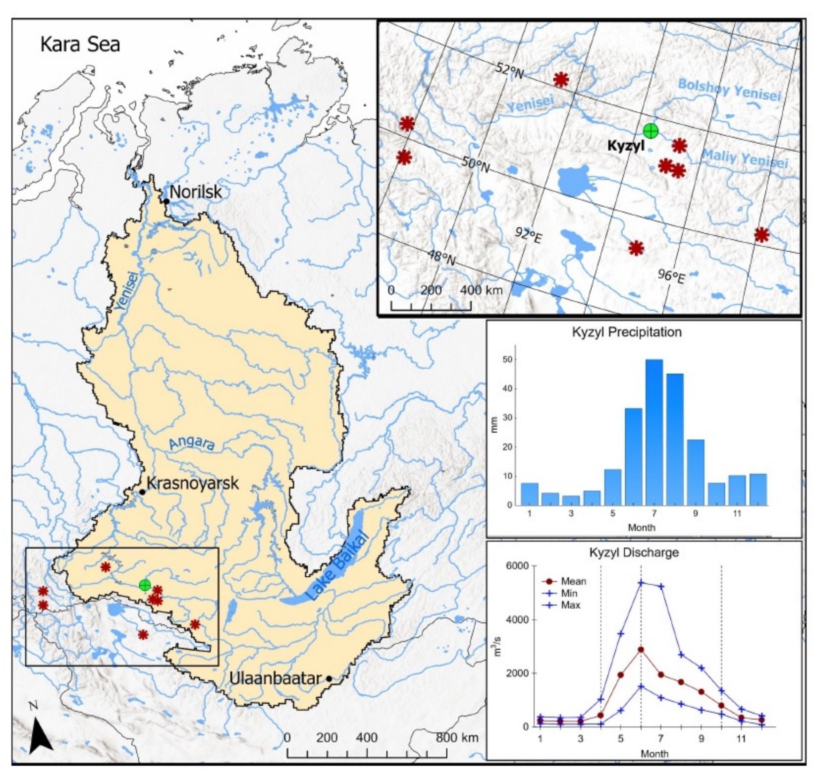


Winter (Nov-Apr) and annual (Oct-Sept) discharge of the Yenisei River at the Kyzyl gauge modeled with the New Hampshire Water Balance Model.

Accelerating warming in the Arctic and fast loss of sea-ice cover unfolding over the last 20 years, is known as Polar or Arctic Amplification. **What do we know about the feedback of terrestrial hydrology coupled with the Arctic system?**





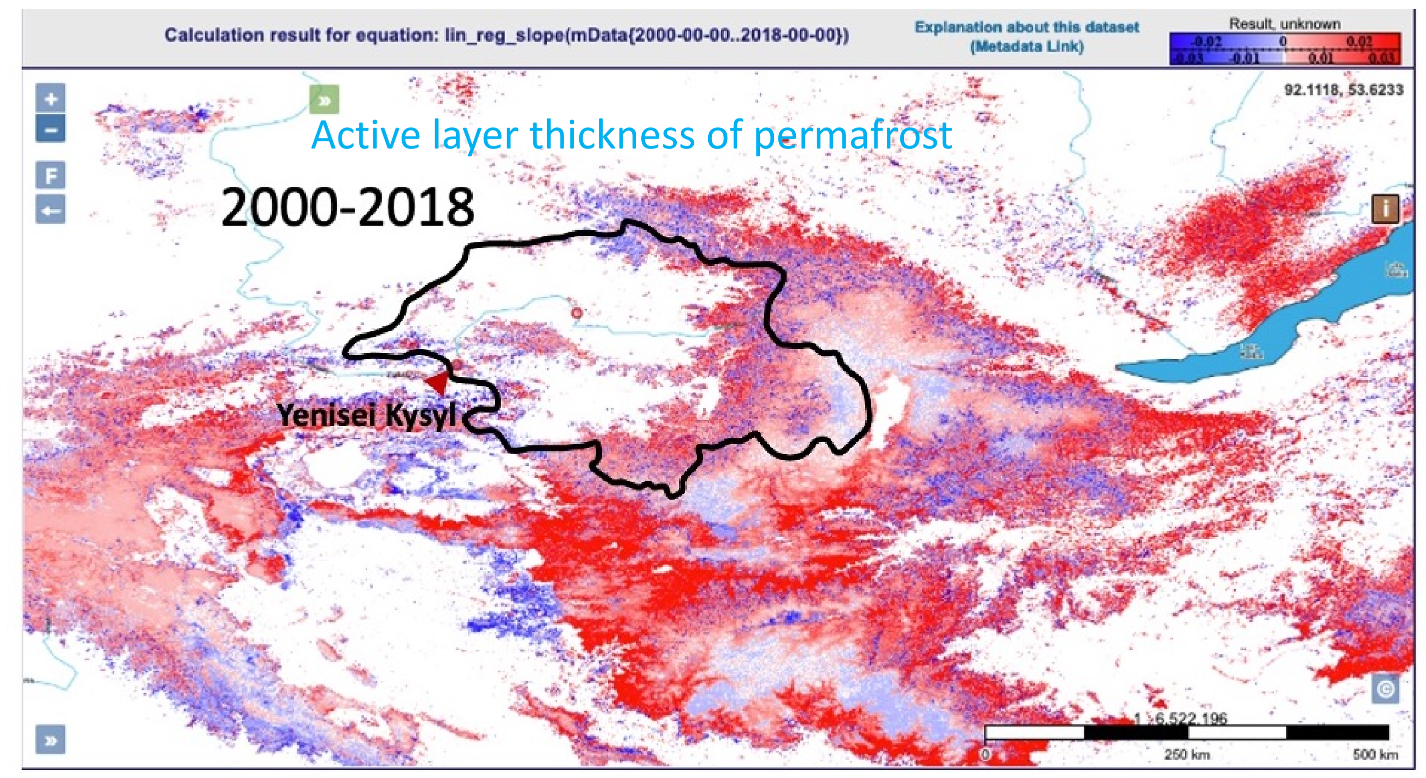


Map of the Yenisei River Basin and tree-ring sites used in the modeling. Hydrograph of the Kyzyl gauge and precipitation at the Kyzyl station. Snow and summer rainfall are the major sources of water in the upper reaches (35% and 42%, respectively). The winter flow relies on the underground water which is 23% of the annual flow. The winter flow measures 12% of the annual discharge and persists longer (140-150 days), while the spring-summer contribution is up to 75%.

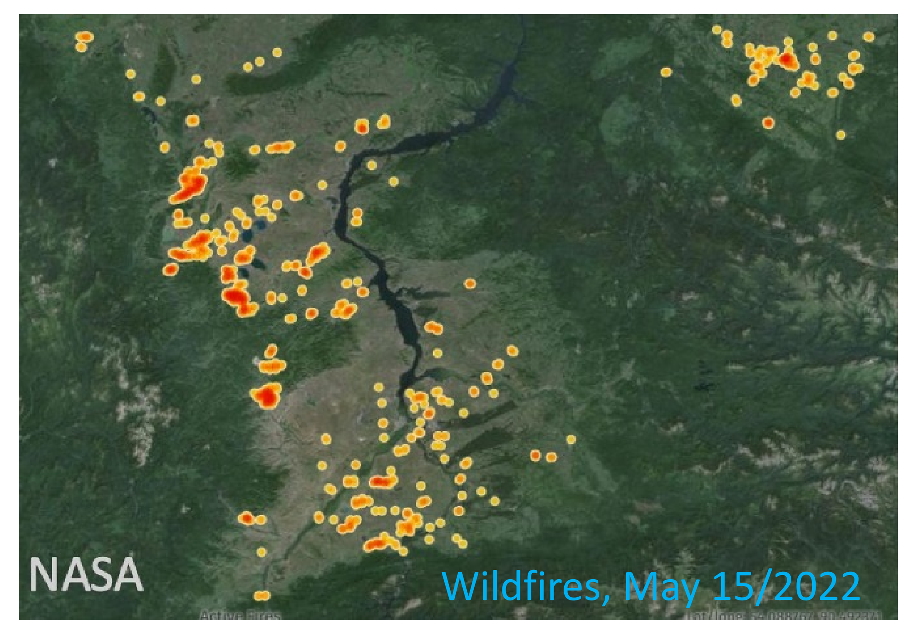
Winter (Nov-Apr) and Annual (Oct-Sept) discharge of the Yenisei River at the Kyzyl gauge reconstructed from larch rings.

We found a remarkable **80% upsurge** in winter flow over the last 25 years, which is unprecedented from 1785. In contrast, the annual discharge shows only a **7% increase** and normal range of variability. Water balance modeling with CRU data indicates a significant discrepancy between decadal variability of the gauged flow and climate data after 1960. Instrumental data shows 7%-20% increase in annual discharge of the major Eurasian rivers like Ob, Yenisei and Lena (1936-2018).

Feedback Loops of Terrestrial Hydrology



As the permafrost degrades, increased connectivity between surface and ground water leads to enhanced ground water discharge and recharge.



As the Polar Vortex wobbles, the weakened Jet Stream causes extreme weather anomalies in the midlatitudes. The long-term impact of wildfire intensity on forest ecosystems and permafrost is another important factor driving the permafrost degradation.