The Yukon-Kuskokwim Delta (YKD) region is one of the most biologically productive areas of the tundra biome and supports one of the largest indigenous human populations in the circumpolar Arctic. Notably, large areas of the YKD are underlain by “warm” permafrost that is highly susceptible to thaw as temperatures warm. Tundra wildfire is a common ecological disturbance in the YKD and a potent permafrost stressor; the summer of 2015 yielded an exceptional number of wildfires in the YKD affecting nearly 300,000 acres, mostly in permafrost-affected areas where vegetation and soils are conducive to fire ignition and spread. The overall ecosystem impacts of tundra wildfire are poorly understood, however, despite the strong relationships between direct impacts of environmental change to ecosystem services and human well-being in the YKD.

We investigated three interrelated topics as part of this project:

1. Impacts of wildfire on YKD upland tundra and permafrost;
2. Changes in surface water in YKD upland landscapes since circa 1950; and
3. Changes in landscape vulnerability to fire resulting from lake drainage and post-fire shifts in vegetation.

This report summarizes the background, activities, publications, presentations, and products associated with each research topic. When available, we provide citations and digital object identifiers (DOI) for published papers and data products. We have also compiled presentations and working manuscript drafts on a shared Google Drive folder at 

<https://drive.google.com/open?id=1D1aBFkiRp-4H8zq8PHZdmvaD9nmgkaVq>
With WALCC support, we collected field measurements, produced quantitative vegetation cover maps, and analyzed long-term satellite records to characterize environmental dynamics and successional patterns following tundra wildfire in lichen-rich upland landscapes of the Izaviknek-Kingaglia uplands (IKU) subregion of the YKD. Notably, this region has a rich fire history that spans many decades, allowing for a longer temporal assessment than recent research that has mainly focused on the short-term effects of recent fire in colder, tussock-dominated ecosystems. Spring and early summer temperatures have increased since the mid 20th century on the inland YKD, increasing the potential for fire ignition and spread. Fire therefore represents a dominant disturbance agent and driver of vegetation dynamics in the region.

In July 2017, we collected detailed vegetation data at a network of field plots spanning gradients of fire history. This dataset indicates several key patterns that are important for understanding the biophysical factors that influence resilience and vulnerability to fire on the YKD. Tundra communities here generally have low vascular plant diversity, and most of the dominant vascular species occur with high constancy regardless of fire history. This indicates that most vascular species are somewhat resilient to fire, or are common enough that some individuals escape fire. The rapid recovery of functional diversity that we observed after fire appears to be driven by the high resilience of vascular plant species and *Sphagnum*. This is consistent with long-standing conceptual models of secondary succession, which predict that the majority of species present during succession are already in place following disturbance, and that the reestablishment of the initial plant community is relatively rapid. We also suggest that the lack of extensive ice-wedge polygons reduces the vulnerability of YKD ecosystems to secondary impacts; polygonal ground in colder tundra ecosystems is subject to dramatic and persistent changes in microtopography and soil hydrology due to thawing after fire.

The rapid recovery of vascular plants contrasted with the much slower recovery of lichens. Floristic differences among plots were primarily driven by nonvascular vegetation, because few lichens survived fire, and several lichen taxa that colonized burned sites were scarce or absent in unburned tundra. The mixed lichen mats found in unburned tundra are frequently 5–10 cm thick; therefore, the recovery of lichens after fire requires longer periods than our cover-based metrics would indicate. The slow recovery of lichens, coupled with the low abundance of tussocks (with
their abundant litter), likely limits typical fire severity and the potential for repeat fire in the IKU. Although ~20% of the IKU has experienced fire since circa 1950, only ~0.8% of the fire-affected area has experienced multiple fires. This is likely because most fire is carried by lichen-rich fuels; recent estimates of reburned areas in tussock tundra of the Seward Peninsula and Noatak valley exceed 15%.

The frequency and severity of tundra wildfires appear to be increasing with climatic warming, indicating that the YKD and Beringia generally—a historic “hotspot” of tundra fire—are likely to experience increased fire activity in the future. Given the high shrub abundance that we observed in historical burns, the YKD’s relatively warm summer climate, and paleoecological evidence that links shrub-dominated Alaskan tundra with a more active fire regime, it appears certain that the region will become increasingly shrubby in the future. Thick accumulations of Holocene peat on the IKU, however, appear to limit opportunities for recruitment of fast-growing, tall shrub taxa (e.g., *Alnus*), and also buffer permafrost against the effects of disturbance and climate change. Nonetheless, fire-induced changes to surface properties could accelerate thawing of permafrost, and contribute to abrupt and persistent changes in habitats and carbon dynamics. Landscape drying, and the concomitant loss of ponds and other natural firebreaks could also increase the potential for repeat burns on the IKU. Our findings provide a basis for predicting and monitoring post-fire tundra succession across climatic and environmental gradients in the Low Arctic.

Publications (1)


Presentations (4)


Products (1)

Frost, G. V., R. A. Loehman, S. B. Saperstein, and M. J. Macander. Field data and fractional cover maps of vegetation across tundra fire gradients, Y-K Delta, AK. ORNL DAAC, Oak Ridge, TN, USA. IN REVISION DOI:10.3334/ORNLDAAC/1772
2: CHANGES IN SURFACE WATER IN YKD UPLAND LANDSCAPES

The YKD is one of the warmest parts of the Arctic tundra biome and its upland landscapes experience an active tundra fire regime. Permafrost is currently widespread and strongly influences terrestrial and aquatic landscape properties, but is sensitive to climate change and disturbance because ground temperatures are near freezing. We have combined field-based and remotely sensed metrics to determine patterns of correspondence between pond drainage and tundra fire history in the YKD’s Izaviknek-Kingaglia uplands (IKU), where the landscape is studded with ponds with small catchments. Extensive fires occurred in the IKU in 1971–1972, 1985, 2006–2007, and 2015. Over the period 1975–2014, pond extent has decreased by ~12% in unburned uplands, consistent with changes observed elsewhere in the discontinuous permafrost zone. Surface water decreases over this period were similar in recent burn scars (2015, 2005–2007), but decreases ranged 22–58% in historical burns (1985, 1971–1972, 1953). Analysis of seasonal water frequency products (e.g., USGS Dynamic Surface Water Extent) indicate that changes relate to persistent terrestrial-aquatic transitions rather than seasonal water frequency. These observations, coupled with field measurements of tundra active-layer thickness (ALT) and modeling of ALT using Synthetic Aperture Radar (SAR) and ground penetrating radar (GPR) indicate similar time lags (~30 years) between peak ALT and pond drainage rates post-fire. The correspondence in timing suggests that progressive increase in active-layer thickness impacts pond water balance, possibly through increased hydrologic connectivity and seepage into thickened active layers. Alternatively, upland pond drainage may be an indirect result of the vegetation shifts observed in Topic 1; the replacement of lichens by shrubs and other vascular plants post-fire likely results in a dramatic increase in evapotranspiration and a concomitant reduction of lateral water flows into lake basins. Although tundra vegetation recovers after fire relatively quickly, secondary impacts of fire related to aquatic-terrestrial habitat transitions are permanent with broad implications for fish and wildlife on the YKD. Counterintuitively, the most dramatic impacts of tundra fire in this region appear to be related to aquatic rather than terrestrial ecosystems.
Publications

We are currently drafting a manuscript on this topic in collaboration with Kevin Schaefer (National Snow and Ice Data Center) and Roger Michaelides (Stanford University). WALCC funding has allowed us to undertake analysis of existing waterbody datasets, but the multidisciplinary aspect of the topic has necessitated additional analysis of Synthetic Aperture Radar (SAR) and airborne remote sensing data in order to reach definitive conclusions regarding this topic. We will continue work on this topic using support from NASA’s Arctic-Boreal Vulnerability Experiment and will update WALCC staff as the data analysis, manuscript preparation, and peer review process are completed. The working draft of this manuscript can be found at the Google Drive link provided above.

Presentations (2)


Products

We will assemble a data deliverable containing maps of waterbody distribution and permafrost properties (e.g., seasonal timing of active layer re-freezing) in relation to fire history and post it at the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL-DAAC), as was done for the data deliverable described above for Topic 1.
3: CHANGES IN LANDSCAPE VULNERABILITY TO FIRE

With WALCC support, we are developing spatial models of landscape vulnerability to future fire in the Izaviknek-Kingaglia Uplands (IKU), a region with a very active fire history and for which we have developed useful datasets for modeling future vegetation (i.e., wildland fire fuel) and waterbody extent (i.e., fire breaks) as part of Topics 1 and 2 above. Our ultimate objective is to produce spatial models of landscape vulnerability to fire to characterize the influence that recent changes in surface water extent and tundra vegetation are likely to have on future fire behavior under different scenarios of fire severity and climate warming. WALCC funding has allowed us to evaluate the performance of existing wildland fire fuel models, such as Wildland Fire Decision Support System (WFDSS) and FlamMap. This work has revealed limitations in existing fire models for predicting fire behavior in tundra ecosystems, which is not surprising considering that these models have been developed for forest ecosystems. However, the detailed vegetation datasets and maps developed under Topic 1 provide a path forward for refining these models for tundra environments. We will conclude work on this topic in 2020.

Publications

The landscape modeling relies on datasets and products derived from the preceding research topics, some of which are still in development. We are currently drafting a manuscript on this topic, led by Rachel Loehman. The project team will update WALCC staff as the data analysis, manuscript preparation, and peer review process are completed. The working draft of this manuscript can be found at the Google Drive link provided above.

Products

As the analysis and manuscript are completed, we will assemble a data deliverable and post it at the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL-DAAC), as was done for the data deliverable described above for Topic 1.