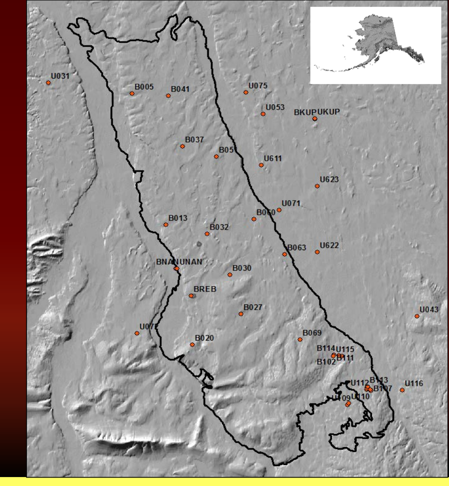
Anaktuvuk R Fire mid-July 2007, photo by Rick Reanier

Tundra Fire Accelerates De-frosting of America's Icebox

Randi Jandt[1], Eric A Miller[2], Carson A. Baughman[3], Benjamin M Jones[3] & Go Iwahana[4]

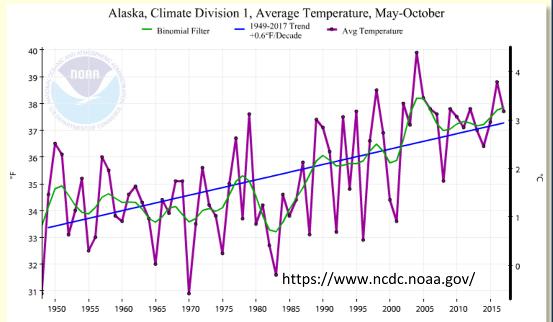
[1]University of Alaska Fairbanks/Alaska Fire Science Consortium (rjandt@alaska.edu), [2]BLM, Alaska Fire Service, Fort Wainwright, Alaska, [3]USGS, Alaska Science Center, Anchorage, Alaska, [4]University of Alaska Fairbanks, International Arctic Research Center



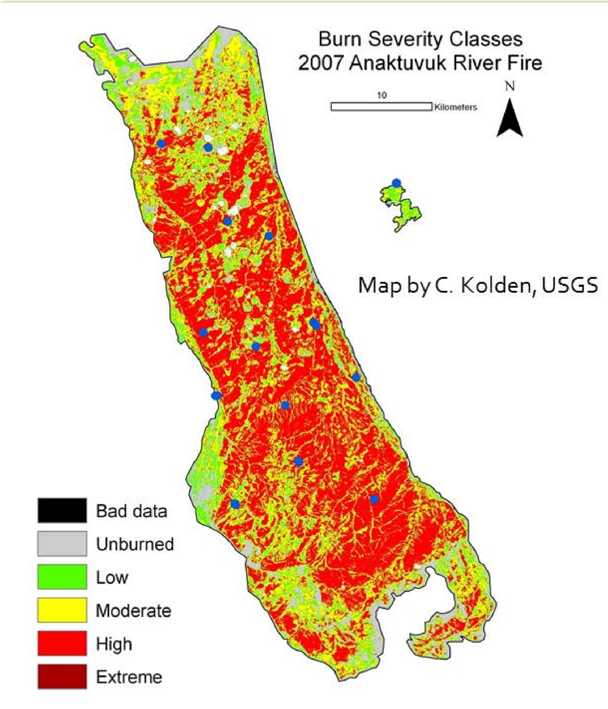
Background:

►**Climate warming is bringing more wildfires, even to the Arctic**. More frequent or deeper burning could rapidly alter the structure and function of high northern latitude ecosystems[1]. Fire weather (summer temperatures, lightning, snow-free days) are changing, leading to more acres burned in Alaska and Canada[2] and nowhere is the rate of warming more profound than arctic Alaska. Modeling burn probability with climate projections indicate tundra areas of arctic and western Alaska may see increases in fire 4-20x greater than historical levels[7]. Some tundra areas are likely to experience fire frequency greater than levels observed in the paleo record, spanning the past 6,000-35,000 years[7].

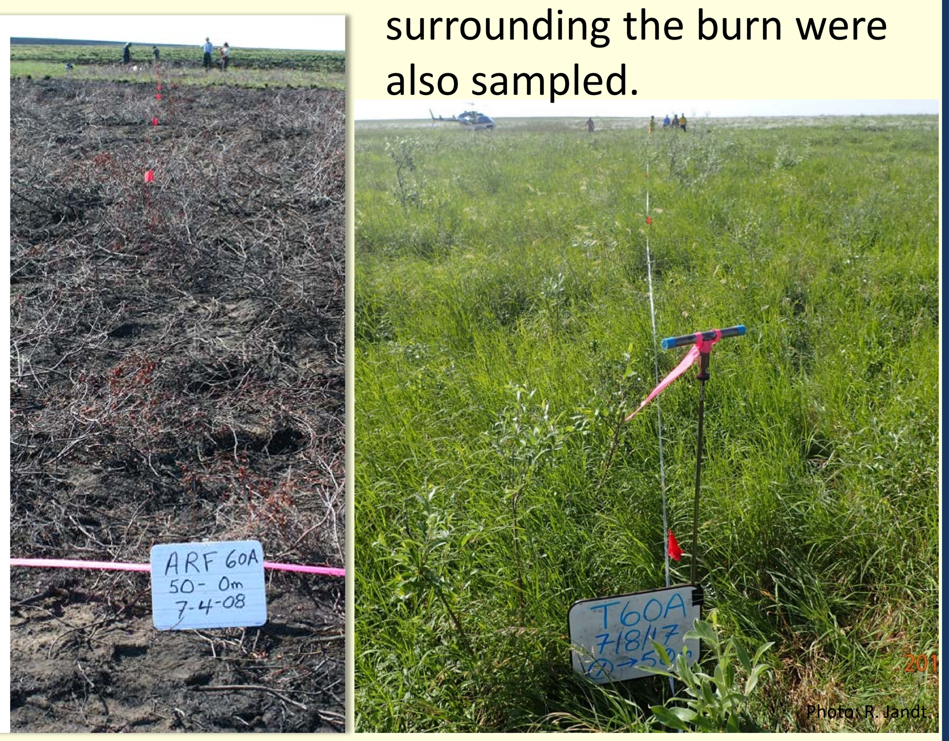
Post-fire thermokarst exposing a rapidly-melting Pleistocene ice wedge 4 years after the Anaktuvuk River fire.



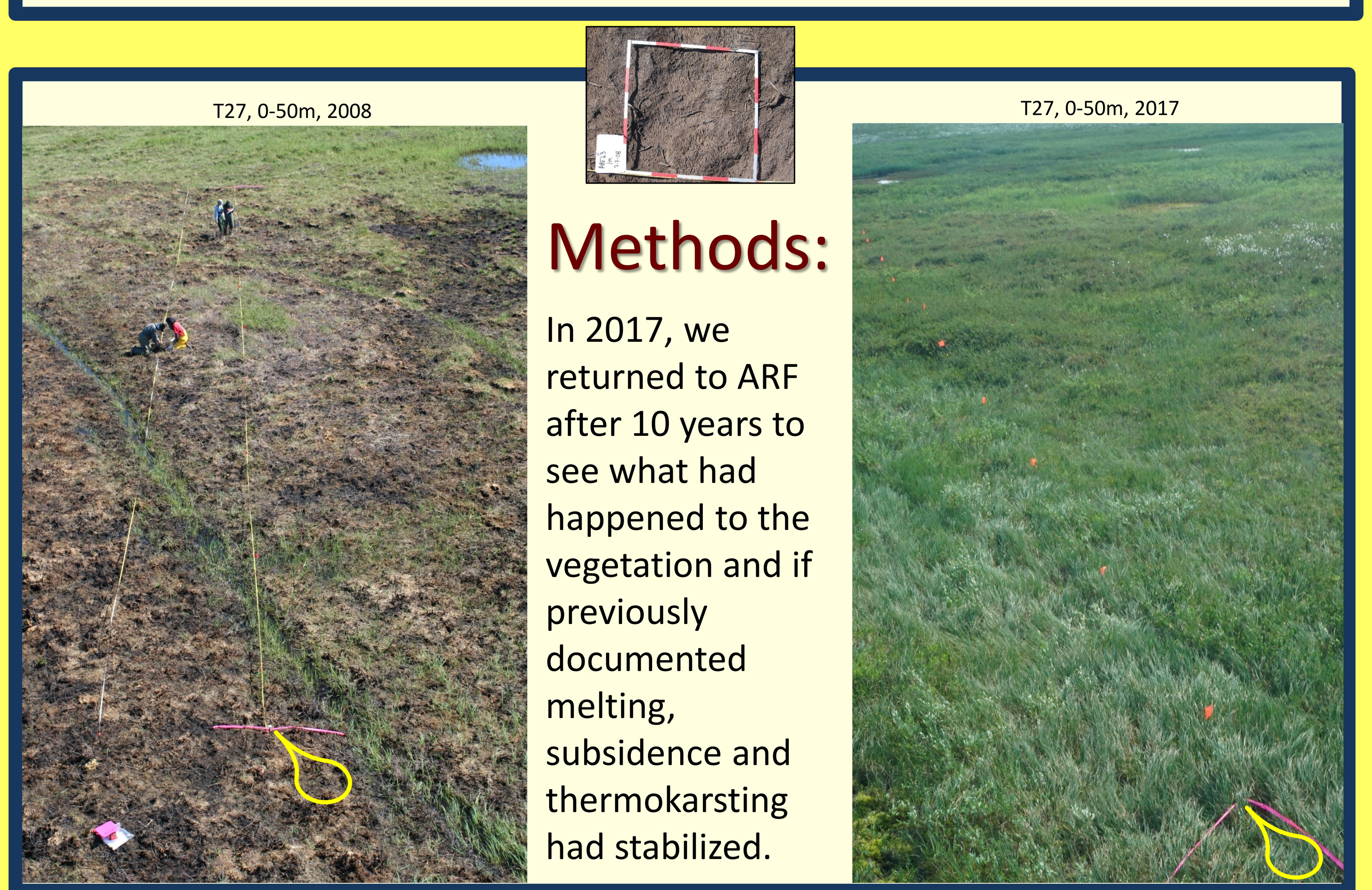
►**The Anaktuvuk River fire** was started by lightning July 16, 2007. In September its growth Accelerated to a rate of 17,000 ac/day, continuing to smolder until covered by snow in early October. Ultimately, 103,600 ha (256,000 ac) were burned. This fire event was unusual enough that agencies formed an interdisciplinary, interagency team to study the fire effects, and establish long-term monitoring transects. 50-m transects (n = 14) inside the burn were measured in 2008-2011 and in 2017 for cover of ground-layer vegetation, tall shrub abundance, thaw depth, and soil properties[6]. Unburned reference transects (n = 11) surrounding the burn were also sampled.



Classified burn severity map based on dNBR methods using ground plot CBI data (blue dots) to ground-truth [4].



T 60A in 2008 (left) and 2017 (right), now lush with grass and regenerating willows (*Salix pulchra* and *S. glauca*) which showed browsing, and signs of spring high water--overland flows 5 m above creek level.

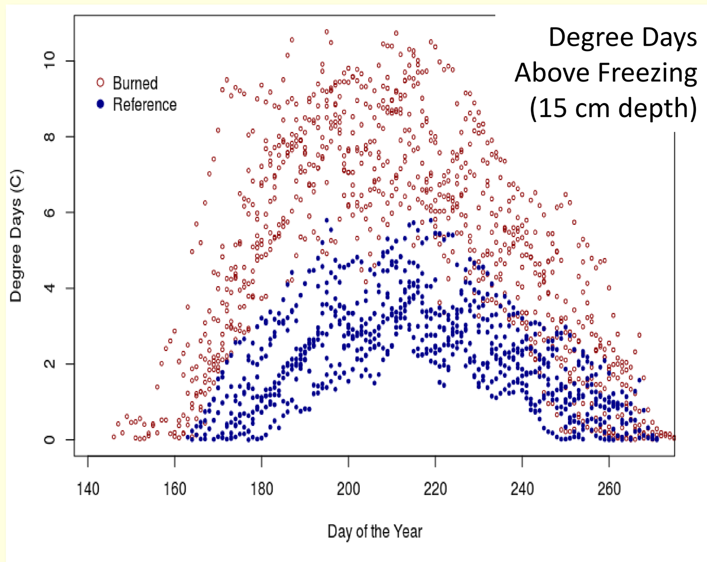


Methods:

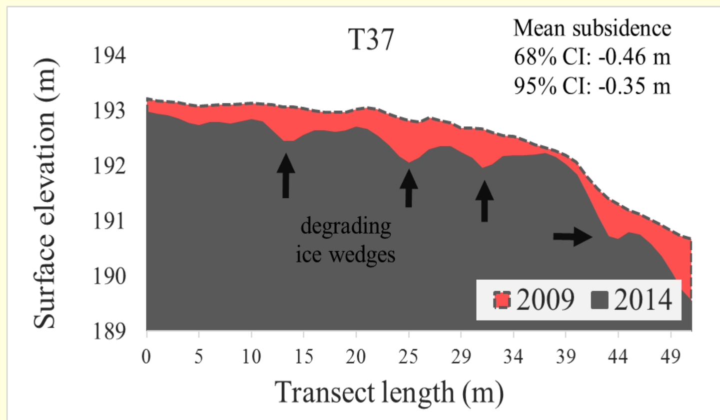
In 2017, we returned to ARF after 10 years to see what had happened to the vegetation and if previously documented melting, subsidence and thermokarsting had stabilized.

Bio-physical changes:

► **Burn severity influenced vegetation recovery:** in lightly burn sites plants regenerated from roots and rhizomes and fire resistant tussocks came back with renewed vigor. Burned cottongrass tussocks continue to grow and flower vigorously, suggesting a continued flush of soil nutrients, competitive release, or a response to warming at root-level. By 2017, severely burned transects had strikingly more grasses and willows. Post-fire accumulation of organic material was 2 - 5 cm of moss and plant litter over a clearly defined charcoal layer. Moss communities in the burn differed in composition from those in reference transects). Fruticose lichens of forage species (5-8% cover in reference transects) were rare in the burn --a few tiny sprigs regenerating in favored locations.

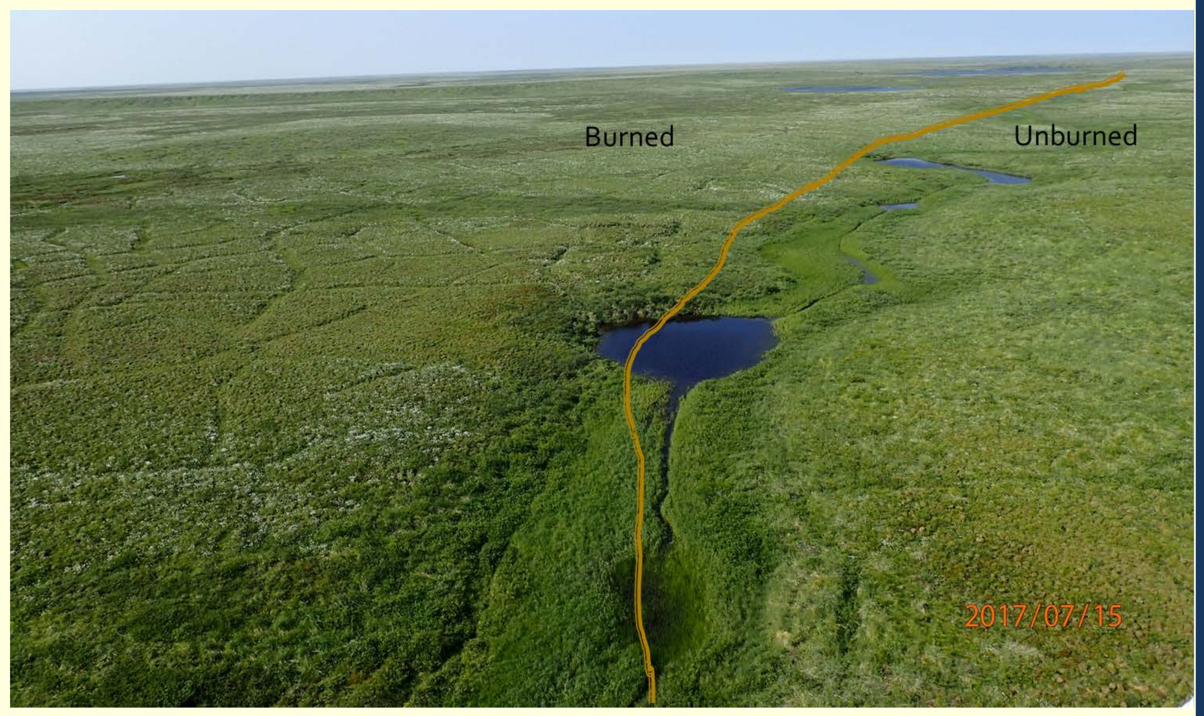


After 10 years the burned transects has 2.7x as many degree days above 0° C, and a 13-day longer frost-free season.



Dramatic surface subsidence was measured at transects underlain by yedoma soils using LiDar.

► **Soils/Hydrology:** Degradation of permafrost features was especially prominent in yedoma soils, less so on glaciated uplands and fluvial soils. We observed ground subsidence >1 m in cases and areas have developed deep thaw cracks, lengthening some transect lines (by as much as 1.8 m!) or shortening others as the organic mat slides and wrinkles over thawing ice. Our aerial photo pairs (N = 26), and LiDar data (see graph) better illustrate the transformation in the land surface that is being driven by changes in the subterranean ice topology. It appears that the tundra initially becomes wetter post-fire, then drier, as water drains through degrading ice troughs and the active layer deepens.



2017 aerial photo showing increased surface toplogy in burned area (left).

► **Subsurface organic soil temperatures** were consistently warmer in the burn (as much as 6°C in summer; 1.7°C annually). Organic soil layers in the burn remained > 0°C about 13 days longer over Season (*see graph above*).

► **Fire regime:** The first two Arctic Slope reburns were discovered inside the ARF. Intensity and severity were light. Simultaneous and unprecendented fires in Greenland[4] suggest the determinants of fire regime operate at a pan-arctic scale.

2017 burn scar inside the 2007 Anaktuvuk River Fire. Burn severity was light. The reddish color is scorched (rather than consumed) dwarf birch leaves. Inset: A new permanent transect was installed in one re-burn.

Implications:

► **Fire appears to lead to:**

1) Accelerated willow expansion and degradation of permafrost features,
2) Preference for fire resistant (e.g., tussock grasses), resilient (e.g., resprouting shrubs), and colonizer (e.g., true grasses, tall willow) plant species, promoting more vascular plant dominance after each fire event.
3) Substantial increases in soil temperature that persist at least 10 years.
4) Increase in surface "roughness": microtopography increased 340% from 2009-2014 where the burnscar was underlain by yedoma[3].

Opportunities for Collaboration:

Jack Ahgook Jr. & Teresa Hollingsworth assess post-fire effects on ARF (2008). Caribou compose 70% of year-around diet for Jack's village of Anaktuvuk Pass, so there is concern about fire effects on caribou habitat and migration routes.

Monitoring the ARF burn over the last 10 years reveals a story much larger than our team can tell, inviting involvement of other disciplines, especially remote sensing investigations. Remote sensing studies could quantify future landform, hydrology, and snow depth changes, and help scale inferences to the larger landscape. Application of remote sensing technology as part of the future monitoring is also desirable due to its cost effectiveness as agency budgets decline.

► **Key questions:** What are changes in fuelbed height? How significant are changes in surface roughness and topology (due to subsidence) and do they correlate with burn severity? What is the fate of forage lichens which take decades to recover and how will caribou respond? How will increasing willow abundance affect snow dynamics, ground-layer plant communities, moose and other animal habitat? How do surface and subsurface layer moisture content change--can we quantitatively confirm our observations of hydrologic changes? Is snow depth altered in burn scars due to surface and/or vegetation change? Here is an *incomplete list* of **ABoVE investigations which may be collaborative**:

Bourgeau-Chavez: Assessing and Downscaling SMAP data for Organic Soil Fuel Moisture Estimation in Boreal-Arctic Ecosystems (2017)
Goetz: Mapping and modeling attributes of an arctic-boreal biome shift: Resource management implications within the ABoVE domain (2015)
Iwahana: Quantification of thermokarst and carbon release in ice-rich permafrost regions (2016)
Loboda: Quantifying long-term impacts of single and repeated wildfire burning in North American tundra on organic soil carbon stocks and ecosystem functioning (2015)
Mack: Increasing fire severity and the loss of legacy carbon from forest and tundra ecosystems of northwestern North America (2015)
Rocha: Following the reorganization and resynchronization of biogeochemical cycles after an unprecedented tundra fire (2016- NSF-LTREB)
Rogers: Developing a spatially-explicit understanding of fire-climate forcings and their management implications across the ABoVE domain (2015)
Schaefer: YKD project--Yukon-Kuskokwim Delta: The Impact of Fire on Active Layer Thickness (2017)
Welker: Nutritional Landscapes of Arctic Caribou: Observations, Experiments and Models Provide Process-Level Understanding of Forage Traits and Trajectories (2017)

Citations:

[1]French, NHF et al. 2015. Fire in arctic tundra of Alaska: past fire activity, future fire potential, and significance for land management and ecology. Intl J of Wildland Fire 24(8):1045-1061.
[2]Hu, et al. Arctic tundra fires: natural variability and responses to climate change. Front Ecol Environ 2015; 13(7): 369–377.
[3]Jones, BM et al. 2015. Recent Arctic tundra fire initiates widespread thermokarst development. Scientific Reports 5:15865
[4]Kolden, CA and J Rogan. 2013. Mapping wildfire burn severity in the arctic tundra from downsampled MODIS data. Arctic, Antarctic, and Alpine Research, 45(1):64-76.
[5]LePage, M (2017). Largest ever wildfire in Greenland seen burning from space. New Scientist-Shorts, August 8 (online).
[6]Mack, MC. Et al. 2011. Carbon loss from an unprecedented Arctic tundra wildfire. Nature 475: 489–492.
[7]Young, AM et al. 2016, Climatic thresholds shape northern high-latitude fire regimes and imply vulnerability to future climate change. Ecography 40: 606–617.