Remote Sensing of Landscape Change in Alaska

Dave Verbyla
Professor of GIS/Remote Sensing
Dept. of Forest Sciences, SNRAS
dlverbyla@alaska.edu

Presentation August 2016 at Arctic SIGNS workshop
In this talk I covered recent landscape-level changes in vegetation productivity, shallow lakes and wildfire from a remote sensing activity, focusing on boreal and arctic Alaska.
The unfrozen season in Fairbanks has increased from about 85 days to nearly 125 days...
The Fairbanks summer climate regime since 1990 is warmest in the past 200 years.
Parmentier et al. 2013 Nature Climate Change.
Linear trends in tundra mean air-temperature and sea-ice concentration (September and October, 1979 to 2011). Linear trends in tundra mean air-temperature and sea-ice concentration (September and October, 1979 to 2011).
Warmer autumn and winter in the past decade have lead to canopy icing events, effecting both vegetation and people. Instead of snow, winter rain and icing events have become more common in boreal Alaska. Here are some more Fairbanks newspaper headlines. A winter with a major power outage effecting thousands is now common.
What about vegetation productivity...how has that changed in the past 2-3 decades?
Here is a satellite image portraying the lanscape much like you would seelooking down from an airplane. The area is the Alaska Range and Denali National Park, with the Parks Highway near the center of the image. Vegetation appears green to most humans, because green light is being reflected more than blue or red light. In other words, Photosynthesis uses energy from the red and blue spectral regions, so plant canopies are relatively low in red or blue reflectance.
Vegetation is relatively highly reflective in the near-infrared spectral region. This is the same invisible spectral region that most remote control devices (such as a television remote) use.
Fortunately, vegetation canopies are the only natural surface that has a higher near infrared reflectance relative to red reflectance. We use this contrast to compute a vegetation index called the Normalized Difference Vegetation Index (NDVI). NDVI can range from -1 to +1.

Non-vegetation surfaces such as clouds, water, soil, gravel bars, rock, burned areas, etc have NDVI values near zero, while in general the greater the plant canopy density and photosynthetic activity, the higher the NDVI value. In this example, willow shrub canopies might have NDVI values ranging from 0.3 to 0.5 while a birch forest canopy might have NDVI values ranging from 0.6 to 0.8.
Here is an example of the maximum NDVI for the entire growing season for Alaska and the Yukon Territory. By looking at a time series of summer maximum NDVI for many years, we can document trends in summer maximum for different areas in Alaska. An increasing trend has been called the "greening trend" and a decreasing trend is called a "browning trend"
This is from Skip Walker's research team. For arctic Alaska is a fairly strong relationship between summer warmth and maximum NDVI. The warmest subzone is Subzone E the foothills of the Brooks Range, while the coldest subzone is subzone C near the Arctic Ocean. The warmest subzone E always has the highest NDVI, and the coldest subzone C always has the lowest NDVI.

Note that for each subzone, the trend since the 1980s has been an increase in peak summer NDVI or the classic greening trend.
So scientists have used historic field photography, there has been a substantial expansion of shrubs in some areas of arctic Alaska. This was part of Ken Tape's PH D work at UAF...
So as climate warms, there is a potential positive feedback with tall shrubs increasing in density....

Note that in the early 1920s moose were restricted to the boreal forest region south of the Brooks Range. Today they range all the way to the arctic ocean along tall shrub corridors such as the Chandalar River.
In boreal Alaska, Beck and his co-authors found NDVI regional trends, consistent with tree ring trends (plots delineated as green or brown circles). A threshold of about 12 degrees separated the positive versus negative trends based on tree-rings.
What really drives peak summer NDVI is summer soil moisture. For example 2003 was a wet summer and 2004 was a drought summer. Spring soil moisture is typically high and not very different.
The declining NDVI trend in eastern interior Alaska is consistent among different landscape positions. Here the south-facing slopes have more broadleaf aspen/birch and thus have a consistently higher NDVI, while the valley bottoms are dominated by black spruce woodlands and have the lowest NDVI. Despite significant vegetation differences among these landscape types the declining NDVI pattern since the 1980s is consistent. This is likely due to regional drought effects.
Walker et al. found a similar pattern looking at black spruce tree rings across a gradient of sites in boreal Alaska. Here we are looking at tree ring growth of black spruce on north-facing slopes versus south facing slopes. And based on these and other results Walker et al concluded that even these cold, moist black spruce sites were experiencing drought stress.
It seems surprising that cold sites in eastern boreal Alaska would be affected negatively by a warming climate. There are a couple of potential mechanisms. In the spring, above ground air temperatures can be very warm with low relative humidity and long warm windy days. Yes the black spruce trees may be on a completely frozen soil insulated by snow, and thus develop canopy water stress. So from Berg and Chapin 1994, there is water stress occurring in late May.

The second problem is that soil temperature is cold on typical black spruce sites. For example, here the soil temperature at 20 cm is below freezing until the beginning of July. Even later in the summer, the rooting zone on these cold sites is typically shallow and not well buffered against summer drought.
Let’s explore some potential consequences of this warming climate in Alaska. Another factor that has likely contributed to the browning trend in boreal NDVI is the infestation of insect populations as the climate has warmed. For example, in southcentral Alaska the spruce bark beetle went from one generation per summer to 2 generations per summer as the climate warmed. Other insects like the aspen leaf miner and willow leaf blotch miner appear on the scene as prolonged infestations for the first time.
What about vegetation productivity...how has that changed in the past 2-3 decades?
Let's talk about changes in shallow lakes associated with climate warming.
We found a similar declining trend in boreal Alaska regions based on aerial photography from the 1950s, early 1980s, and Landsat satellite imagery post 2000. During the same time period there was a significant increase in most boreal climate stations potential evapotranspiration.
On the Seward Peninsula, in a region of discontinuous permafrost Yoshikawa and Hinzman found drainage through taliks to be the dominant mechanism of shrinking lakes since 1950.
In regions of upwelling, there has been expansion of thermokarst lakes and “drowning of forests”. Here from Google Earth, many of the mature birch trees are down and easily seen.
Up to this point most of the remotely sensed NDVI analyses presented have been for areas that have not recently burned. But with a warming climate, increased fire frequency and fire severity is likely and this will continue to be a big story in boreal Alaska. Here in 50 years since 1940 approximately 12.8 million hectares burned.
In less than half the previous period (24 years) over 13.8 million hectares burned in Alaska!
Most wildfires occur in this eastern region of boreal Alaska.
2007 was a record year in terms of lightning strikes, yet a low wildfire year due to frequent showers throughout the summer.
2013 was a record summer with the most days ever recorded above 80 degrees F. Despite a hot dry summer, there were few wildfires because there were relatively few lightning strikes.
2004 was both a hot dry summer and a summer of high lightning activity. It was the record year for wildfires in Alaska.
Questions?