Remote Sensing of Landscape Change in Alaska

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In this seminar I will broadly cover three landscape changes in Alaska: shallow lakes, vegetation productivity, and wildfires...all fairly easily to map and monitor from remote sensing., and all likely to change due to climate warming in Alaska.
One advantage of satellite remote sensing is the ability to go back in time...for example Smith et al. used Landsat imagery and published a paper in Science “They looked at only changes in relatively large lakes and in a time series of only 2 time periods. However, they found a consistent declining trend in regions of non-continuous permafrost.
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.
In Riordan et al. 2005, we found stable lakes (A, B, C) adjacent to shrinking lakes (D, E, F) to be common...Jen Roach explored potential mechanisms by field measurements of these “paired lakes”. The dominant mechanism for the Yukon Flats and Innoko study areas was terrestrialization or expansion of emergent vegetation, which I would expect in these eutrophic lakes.
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.
On the Kenai Peninsula, in a permafrost-free region Klein et al. found up to 40 percent of lakes lost over half their area since 1950, most likely due to increased potential evapotranspiration during the period. By aging shrublines along the lake margins, they found that shrinkage occurred in distinct pulses.
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.
Jorgensen et al documented this trend in the Tanana Flats of declining ("drowning" birch forest) and increasing fens based on aerial photography.
In the Yukon Flats, based on Landsat imagery there are clusters of decreasing and increasing shallow lakes (Rover et al. 2011)
On the northern Seward Peninsula, in a region of continuous permafrost Jones et al found a consistent expansion of thermokarst lakes. This expansion would not be detected using Landsat imagery with 30-meter pixels and could only be detected using high spatial resolution imagery.
There is typically both lake shrinkage and expansion occurring in most Alaskan landscapes. In the northern Seward Peninsula, Jones et al. documented a net decrease in lake area due to thermal erosion and catastrophic drainage, but a net increase in the number of lakes due to thawing of permafrost.
Add a different scale, Necsolu et al. documented a similar pattern on high resolution aerial photography from the 1950s and 2000 decades...areas in blue became wetter and areas in yellow became drier.
Using a time series of at least 5 landsat scenes from each region, Roach et al. found most regions to have either declining lake area trends (red), no significant Trends (green) or significant increasing trends (blue). Using a multivariate model, soil texture and distance from rivers were important variables. Wildfire increased the probability of decreasing trend (red versus blue surface).
Vegetation productivity trends typically are estimated using a time-series of NDVI which is an index of photosynthetic activity.
There are typically many samples that are initially acquired, and then the sample with the maximum NDVI is retained in a weekly or biweekly NDVI image.
Typically the maximum NDVI from the entire growing season of a year is extracted for each pixel.
Maximum NDVI for each pixel over many samples from June 1-15
The maximum greenness has declined in interior Alaska, while at the same time it has increased north of the Brooks Range, probably associated with Climate warming (increased shrubs in the Arctic tundra, drought stress and insect/disease in interior Alaska). Areas that burned in the past 30 years were excluded in this analysis.
In arctic Alaska, there is a lag in NDVI response with the previous year’s summer warmth index.
Beck et al. also found similar regional patterns in Alaska, 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.
Looking at all of North America, Beck and Goetz have shown the percent of boreal forest declining in NDVI has increased since 2002, while tundra has increased in the percent of area with increasing NDVI trends.
In boreal Alaska, some of the declining NDVI is likely due insect infestations in addition to drought stress.
Although the tundra regions typically have an increase in NDVI, at a smaller scale retrogressive thaw slumps are occurring, likely due to warming events. Here a time series of aerial photography (1978) and Landsat imagery can be used to date the initiation and duration of a thaw slump.
Expanding shrubs could decrease sedimentation in arctic Alaska.
Here we used a time series of July 1986 and July 2009 to map expanding shrub areas in four frames and a SPOT image frame. Based on lake cores from four lakes, there was a declining rate of erosion in three of the four lakes since 1980, perhaps due to shrub expansion in these watersheds.
Approximately 11.6 million hectares burned from 1940 through 1989
Approximately 12.3 million hectares burned from 1990-2012
Jones et al. 2013 *Identification of unrecognized tundra fire events*
With a warming climate, tundra fires like the 2007 Anatuvik Fire may be more common on the Arctic Coastal Plain and foothills of the Brooks Range. The accelerated terrestrial warming due to rapid sea ice decline has been projected to be especially substantial during the autumn...a time when active layer is at it’s maximum and the potential for deep burning is the greatest. The Anatuvik fire started in July and “blew up” in September.
Repeat burns are more likely to occur during an extreme fire season. The Eureka Creek burn above was a black spruce forest that was a moderate burn from the 1980s that reburned during the 2004 fire season.
The contrast of increasing SWIR and decreasing NIR (due to canopy consumption) is the basis for fire severity remotely sensed index.
We found a strong correlation from field based CBI and the remotely sensed severity index for an uplands burn in 1999.
It is a simple process to map fire severity classes using threshold values.
Despite these sources of noise, the Park Service has found some strong correlations (Yukon Charley 1999) between NBR and CBI. Why did the three teams all find weak correlations from Boundary 2004?
The relationship probably falls apart after the stage where branches are consumed by fire and there is high variability of the remotely sensed index at high fire severity sites.
We published this in Remote Sensing of Environment. The correlation between dNBR and CBI was weak above a CBI of 2.0.
Here is an example of three severity burned sites, with high variability of the remotely sensed dNBR.
Fire severity was the same for the pixels in the Boundary Burn since these pixels burned before Aug04. The dNBR values were influenced by phenology and solar elevation with different pre-fire and post-fire image dates used to compute dNBR.
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 Fairbanks summer climate regime since 1990 is warmest in the past 200 years.
The unfrozen season in Fairbanks has increased from about 85 days to nearly 125 days...
Temperature induced drought stress of the boreal vegetation is likely more frequent and more severe after 1990.
Questions?