Examining Tundra Greening from Ground-based to Satellite Observations

Karl F. Huemmrich[a], Sergio A. Vargas Z.[b], Craig Tweedie[b], Petya P.K. Campbell[a], Robert Hollister[c], Elizabeth Middleton[d]

[a]University of Maryland Baltimore County, Code 618, Goddard Space Flight Center, Greenbelt, MD, USA, huemmric@umbc.edu; [b]University of Texas El Paso, El Paso, TX; [c]Grand Valley State University; [d]NASA/GSFC

Shrubs Graminoids Forbs

Introduction

Multiple studies have shown positive multiyear trends in satellite measured Normalized Difference Vegetation Index (NDVI) in tundra ecosystems. These positive trends are often referred to as “greening.” However, the ecological meaning of these trends is not clear at this time. Ongoing ground data collections of tundra spectral reflectance and plant type cover begun in 2010 near Utqiaġvik (Barrow) and Atqasuk, on the Alaskan North Slope provide a unique opportunity to link ground measurements to moderate-resolution satellite observations, such as MODIS, illuminating how surface characteristics relate to arctic greening inferred from satellite data.

Measurements

Visible-near infrared spectral reflectance were collected in Utqiaġvik and Atqasuk at points in the Circumpolar Active Layer Monitoring (CALM) grids. The CALM grid measurements were 30 plots arranged in a 5 by 6 matrix with plots separated by 100 m along each row and column providing a repeatable set of measurements that sample areas approximately the size of a MODIS pixel. Ground measurements were collected using a Unispec-DC spectrometer at multiple times during the growing seasons to temporally sample seasonal growth. Spectral reflectances were convolved to match MODIS bands 1 and 2 for calculation of NDVI.

MODIS 8-day composite surface reflectance observations from Aqua (MYD09) were extracted using the ORNL DAAC online subsetting tool for the pixel that includes the center point of the CALM grid. The Aqua data covered the time period from 2002 to 2018. NDVI was calculated using reflectance from MODIS bands 1 and 2. Poor quality observations were removed and filled in using linear interpolations between the good quality observations.

Plant coverage was measured using point drop method for 100 points within a 70 cm square frame recording green cover by vegetation type. All hits were recorded, so total coverage may be greater that 100% due to the 3-dimensional canopy structure

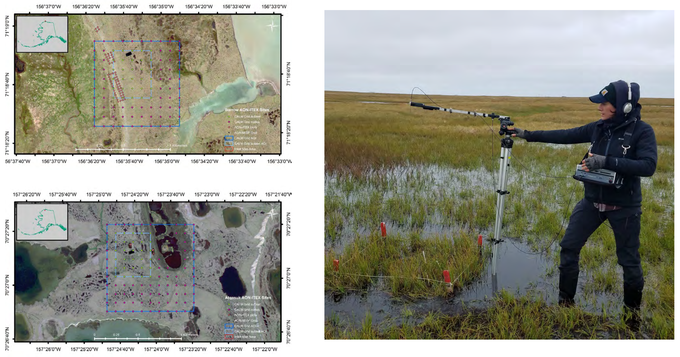

Figure 1. True color World View 2 images from summer 2013 show the Utqiaġvik (upper left figure) and Atqasuk (lower left figure) study areas including the CALM grid (red points) and study subset (blue points). Right picture shows reflectance measurements being collected.

Temporal Change in NDVI

The average of the ground measured NDVI matches well with the MODIS NDVI (Fig. 2).

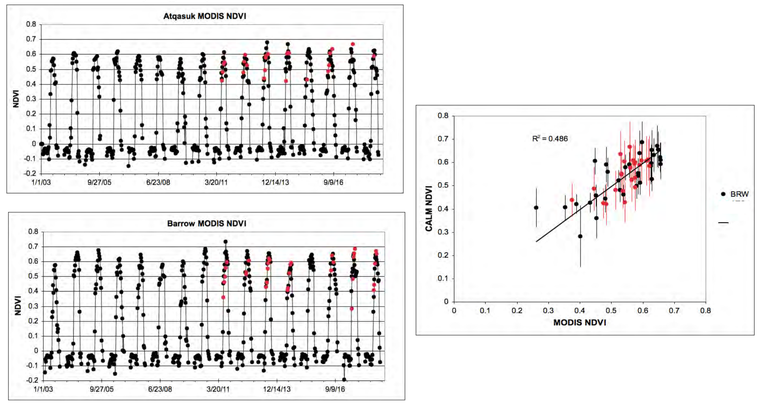

Figure 2. Time series of good quality and interpolated 8-day NDVI from Aqua MODIS for Barrow (upper left plot) and Atqasuk (lower left plot). Red points are the average NDVI of the CALM ground measurements.
Right plot is average of ground measured CALM grid NDVI versus the MODIS NDVI 8-day composites for the pixel that contains the center point of the CALM grid. Error bars are ± 1 standard deviation of the CALM observations. Black points are for Barrow and red points for Atqasuk. Line is 1:1 line

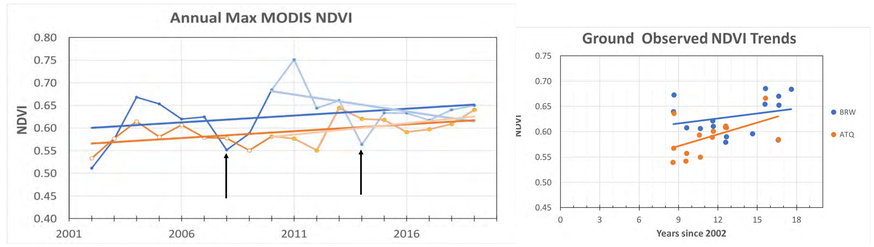

Figure 3. Left figure: midsummer NDVI from ground CALM grid measurements over the period 2010-2018 for Barrow. Black line is 3rd order polynomial fit used to describe seasonal NDVI patterns to calculate de-seasonalized NDVI anomalies for multi-year trend analysis.
Right figure: De-seasoned NDVI anomaly trends for midsummer values. X-axis is years since Jan. 1, 2002. Filled points are good quality MODIS NDVI for Barrow (black) and Atqasuk (red). Solid lines show multiyear trends over the MODIS data period. Open points are average CALM grid ground measured NDVI anomalies with black and red for Barrow and Atqasuk respectively. Dotted lines are multiyear trends for the CALM data.

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References: Cover data from Harris et al. Arctic Science 8: 878–898 (2022) dx.doi.org/10.1139/as-2020-0050
Meteorology data from Daymet at ORNL DAAC https://daymet.ornl.gov/

Sub-Pixel Spatial Heterogeneity

Spatial heterogeneity can influence the observed signal at the coarser MODIS resolution. This heterogeneity is described by examining the distribution of the 30 individual CALM grid plots (Figure 5).

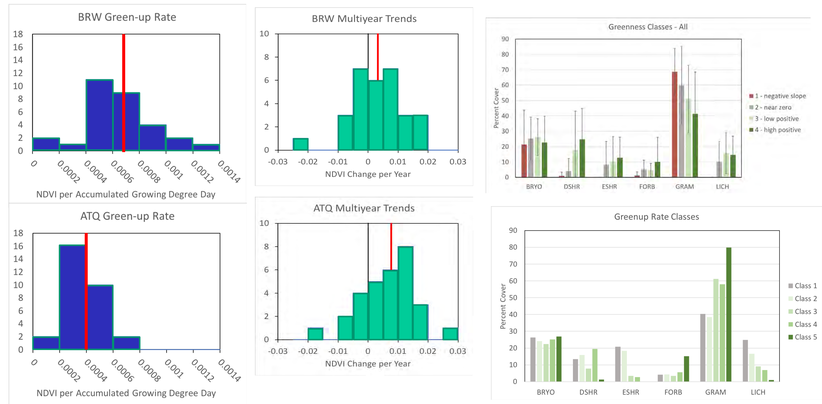

Figure 4. Left figures: Histograms of NDVI responses to warming during springtime green-up for the 30 individual CALM grid points, with the red line marking the trend for the CALM grid NDVI average. Warming is based on accumulated growing degree days (GDD) using 0˚ C as a base temperature.
Right figures: Histograms of de-seasonalized NDVI trends over 2010-2018 for the 30 individual CALM grid points, with the red line marking the trend for the CALM grid NDVI average (dotted trend lines in Fig. 3).

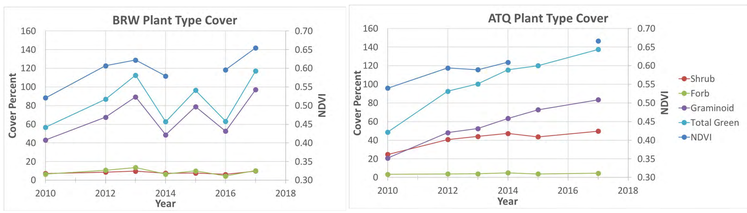

Figure 5. Average CALM grid ground measured green plant cover and NDVI.

Discussion

Spatial and temporal sampling are important considerations in understanding tundra ecological change. Our ground sampling approach was able to produce repeatable observations with similar values to MODIS NDVI values (Fig. 2).

The ground measurements were not collected frequently enough to use the usual satellite NDVI metrics like annual maximum NDVI. To calculate multiyear NDVI trends seasonal NDVI patterns were determined to calculate NDVI anomalies. Multi-year trends from the anomalies showed that the ground measured NDVI trends over the CALM data period were similar to the longer term MODIS trends (Fig. 3).

The ground measurement sampling provided a description of the spatial heterogeneity within a MODIS pixel and showed that within a pixel with a greening trend, there were areas that are browning, not changing, or greening at a greater rate, and that responses to springtime warming also vary across the landscape (Fig. 4).

For these sites the greening trend is mostly driven by an increase in graminoid coverage, and NDVI successfully tracks the change in green vegetation cover (Fig. 5).