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Satellite-based Monitoring of Climate Effects and Disturbances in the Boreal Forests of the Yukon River Basin

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Introduction

Climate change effects at high latitudes produce hot spots, which provide important clues regarding future regional ecosystem responses. Identification of such hot spots and their trends in ecosystem performance indicate probable future regional impacts and areas vulnerable to crossing ecological tipping points. Interannual climatic variations cause similar differences in ecosystem performance, which could mask the dynamics of changing permafrost, insects, or soil drainage. Our approach accounts for interannual climate variability to identify areas that respond to climate in an anomalous fashion in the boreal forests of the Yukon River Basin (fig. 1).

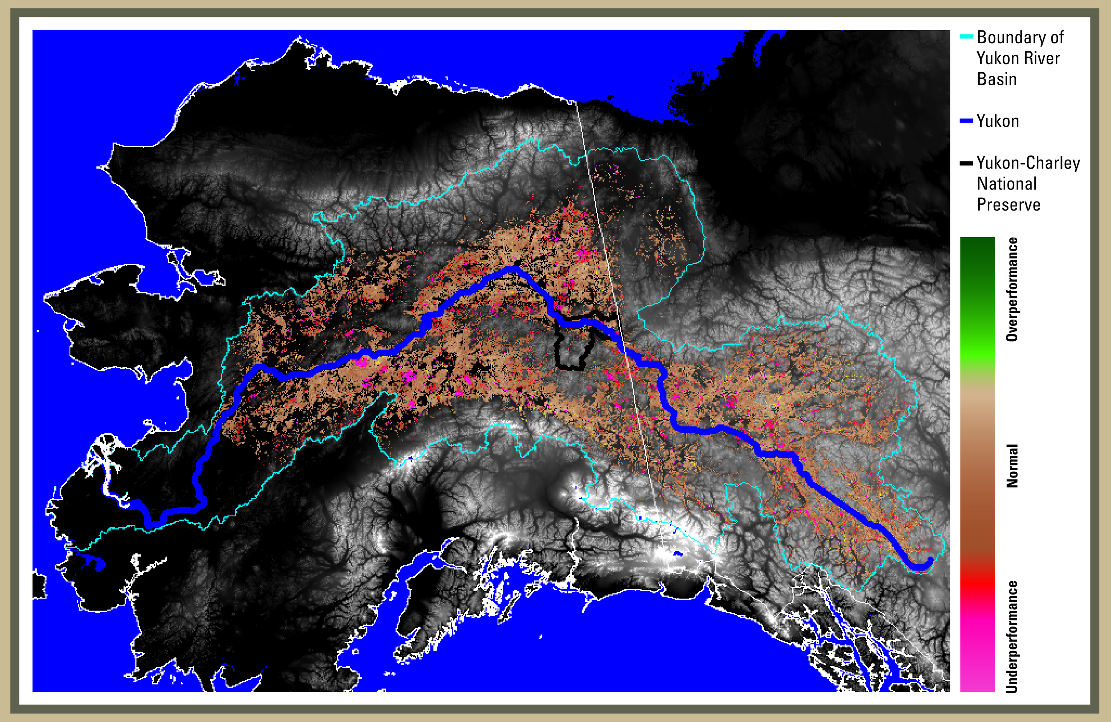

Figure 1. Ecosystem performance anomalies for boreal forests in the Yukon River Basin for 2001 (Yukon Charley National Preserve outlined in black).

Methods

We have developed a regression tree model to estimate the growing season integral of Normalized Difference Vegetation Index (GSN), a proxy for ecosystem performance, from site potential and seasonal climate data. This model is developed from large numbers of random pixels spatially stratified across multiple years. A regression with 90 percent confidence limit helps identify performance anomaly thresholds (fig. 2). These performance anomaly areas are mapped annually (fig. 1), and multi-year anomaly frequencies and trends are also mapped (fig. 3). Boreal forest anomalies are mapped with both 1-km AVHRR data (Alaska only) and 250-m resolution MODIS-derived data for in the entire Yukon River Basin (except the westernmost extent.)

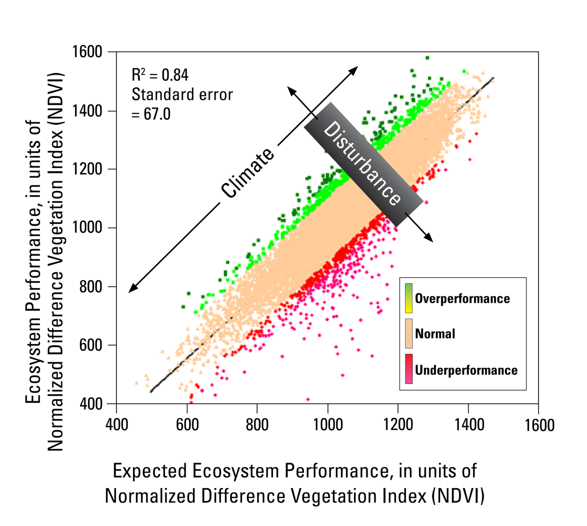

Figure 2. Ecosystem performance anomaly thresholds determined from 90 percent confidence intervals derived from AVHRR, 1996 to 2004.

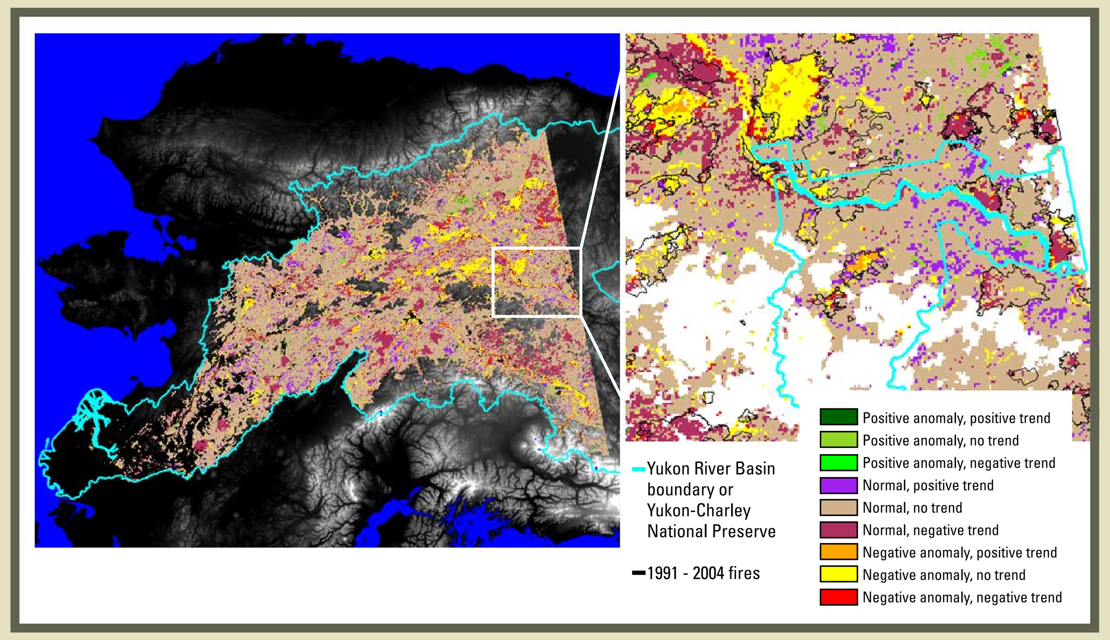

Figure 3. Frequency and trends of boreal forest ecosystem performance anomalies in the Yukon River Basin of Alaska derived from AVHRR for 1996–2004. The insert shows Yukon Charley National Preserve and fires occuring between 1991 to 2004.

Results

The 2004 AVHRR performance anomalies were compared along a burned to nonburned gradient with a moisture index derived from a 2006 Landsat image for two fires (fig. 4). Performance anomaly values between –110 and 110 are defined as pixels performing normally both outside burned areas and within unburned islands. Pixels with ecosystem performance anomaly values less than –110 are underperforming anomalies within the burn. This agrees with indices derived from Landsat and is consistent with gradients of burn severity.

The AVHRR performance anomalies were correlated with field-collected composite burn index data (table 1) from Epting et al. (2005). The composite burn index data were collected to validate 30-m resolution Landsat data, so poorer correlations are expected with the coarser resolution 1-km performance anomaly. This confirms expected underperformance in known burned disturbances. The spatial agreement of performance anomalies

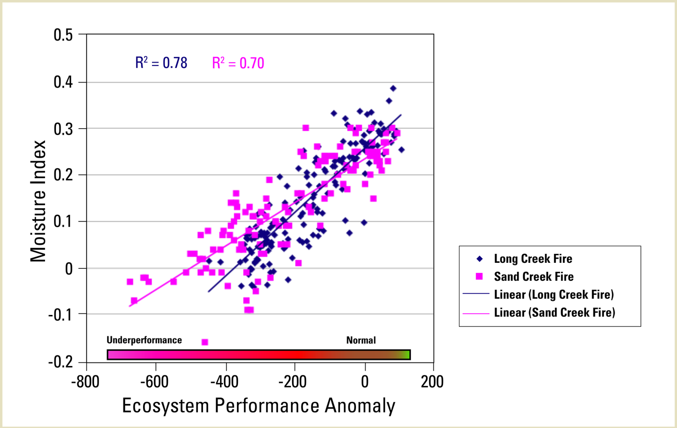

Figure 4. Agreement between Landat 2006 moisture index (band 4 – band 5)/(band 4 + band 5) and 2004 ecosystem performance anomaly across burned to nonburned gradients in two fires.

(fig. 3, inset) and burn perimeters is striking and, as expected, confirms fire disturbances. Performance anomalies do occur in nonburned areas and areas not recently burned. These may indicate changing water dynamics, insect infestations, or changing permafrost.

Table 1. Agreement between the difference of prefire and postfire ecosystem performance anomalies and the Composite Burn Index.

Fire (n)	Statistic	Years 2001	2002	2003	2004
242 (11) Witch fire[1]	R^2	0.66	0.75	0.70	0.75
	MSE	0.40	0.29	0.35	0.29
260 (13) Jessica fire[1]	R^2	0.55	0.43	0.68	0.68
	MSE	0.30	0.38	0.21	0.21
288 (14) Otter Creek[2]	R^2		0.57	0.58	0.54
	MSE		0.24	0.24	0.26

[1] Burned in 2000

[2] Burned 2001

The interannual consistency of performance anomalies and their trends (is underperformance becoming more severe?) help identify possible and potential climate change hot spots and areas under ecosystem stress or areas vulnerable to ecosystem change (fig. 3).

Future Applications

We are also developing performance anomaly maps for the North Slope of Alaska to help document areas of significant increase in shrub cover. We plan to develop this approach for multiple land covers within the Yukon River Basin. This approach is also potentially useful to predict ecosystem performance in future climate change scenarios.

Epting, J., D. Verbyla, and B. Sorbel. 2005. Evaluation of remotely sensed indices for assessing burn severity in interior Alaska using Landsat TM and ETM+. Remote Sensing of Environment, 96(3-4): 328-339.

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