Rising Temperatures and Phenological Change in Northeast North America

A Comparison of SPOT Vegetation NDVI data and MODIS IGBP Land Cover Data.

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Abstract

Current research shows a trend of global climate change and warming temperatures. This climate change is having numerous effects across the globe including altering land cover and ecosystems. Evidence indicates that northeastern North America is experiencing both warming temperatures and a change in vegetation cover. This study investigates if there is a correlation between warming temperatures, NDVI and the change in different land covers in Eastern Canada. Temperature data will be the yearly air temperature average of Montreal, Quebec (low latitude), Labrador City, Labrador (mid-latitude), and Kuujjuaq, Quebec (high latitude) over a 31 year period (1982- 2012). For vegetation analysis was completed using a composite of three SPOT NDVI ten day maximums to create NDVI SPOT30- day maximum value composite, across a thirteen year study period from 2000-2012. land cover analysis was obtained using the International Geosphere Biosphere Programme (IGBP) and MODIS-derived Net Primary Production (NPP) land cover classifications from the MODIS Terra and Aqua from 2001-2009. The main analysis was done with the Earth Trend Modeler in the Idrisi image processing software along with other areas of investigation. If temperatures are rising then there should be a rise in NDVI and a correlated change in land cover.

Introduction

High latitude ecosystem's vegetation is limited by short growing seasons, indirect sunlight and cooler temperatures. These factors limit the NDVI strength and dictate land cover in northern regions. NDVI is directly correlated with health of vegetation and land cover type; therefore it is environmentally essential to monitor NDVI and land cover to understand the health of the regional biome. NDVI is weakest at the beginning of the growing season and strongest at the very end. At latitudes greater than 45 degrees the growing season starts in May and ends in October, therefore this study will focus on those two months. Looking at the maximum and minimum NDVI composites shows the true change caused by temperature;

In eastern Canada, specifically Quebec, Labrador and Newfoundland, there are five major land classes: tundra, wooded tundra, boreal forest, deciduous forest, and boreal/deciduous mixed forest. These land classes cover eighty-five to ninety percent of the study area and dictate the majority of the regional NDVI. NDVI strength is correlated with the specific vegetation cover, and is directly related to the size of the plants, leaves and the growing season of each land cover. For example, the NDVI for a broad leaf deciduous tree in summer is much higher than its boreal counterpart. The contrary is true for fall and winter months. Tundra has the weakest NDVI and shortest growing season.

The study duration varies based on when the data was collected. Complete MODIS land cover data is only available from 2001-2009, SPOT NDVI is only available from 2000-2012, & air temperature for the selected three cities was sporadically available from 1982-2012. As temperatures rise we can expect a change in land cover and NDVI.

Methodology

MODIS – derived land cover is made available online through NASA's Earth Observing System Data and Information System. Data is presented as a yearly composite for a number of different land cover classification schemes in HDR format. The HDR files for the desired years were acquired according to their path and row numbers. For the study, images from path/row 12/03, 12/04, 13/03, 13/04, 14/02, 14/03, and 14/04 were collected for 2001 through 2009. The HDR files were imported into Idrisi Selva Edition (Clark Labs), where the images for land cover type 1 and type 4 were extracted and saved as separate raster (.rst) files. Once all images were extracted, a mosaic was created using the CONCAT tool, resulting in a type 1 and type 4 image for each year. Type 1 (IGBP) is based on an unsupervised classification of MODIS NDVI data; while type 4 is an unsupervised classification of net-primary production (NPP), which correlates nicely with NDVI.

Since the imported files were in an equal area sinusoidal projection, they were used to conduct the area calculations for each land cover type. A vector polygon of Quebec and Newfoundland was converted to a raster using the RASTERVECTOR command in Idrisi. The mask was re-projected from a geographic projection to MODIS sinusoidal and applied to each mosaic using the OVERLAY command in Idrisi. A numeric histogram was created for each masked mosaic and saved as a Unicode text file. Each text file was imported into Microsoft Excel to calculate areas. Using the original MODIS image pixel resolution of 500 meters, each cell containing pixel frequency was multiplied by 2500, resulting in area in square meters. (Divided by 1000 to get square kilometers).

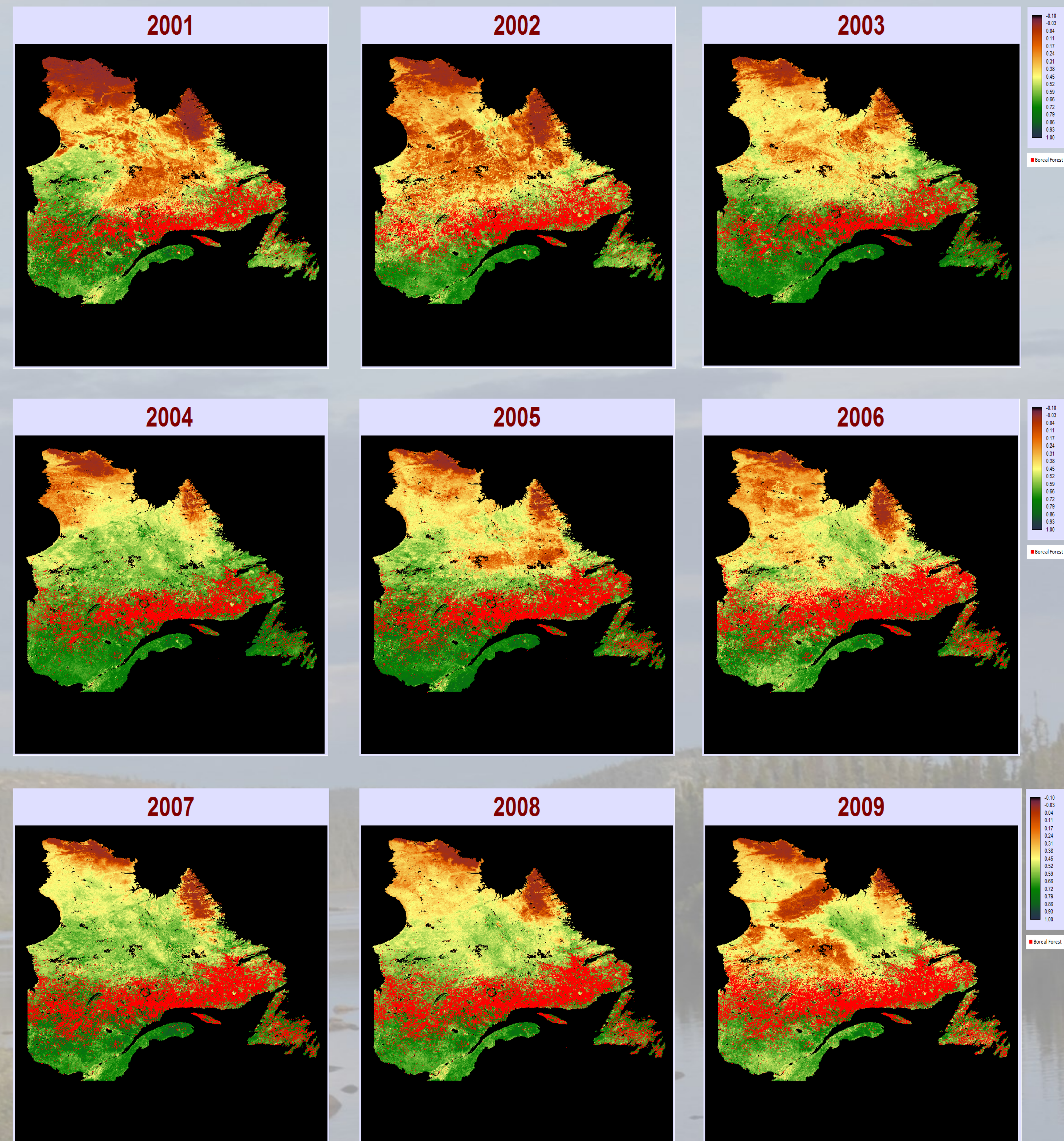
For final presentation images, the masked mosaics were reprojected to a geographic (latitude/longitude) projection using the REFORMAT command in Idrisi. The number of columns was set to 21800 and rows set to 4800.

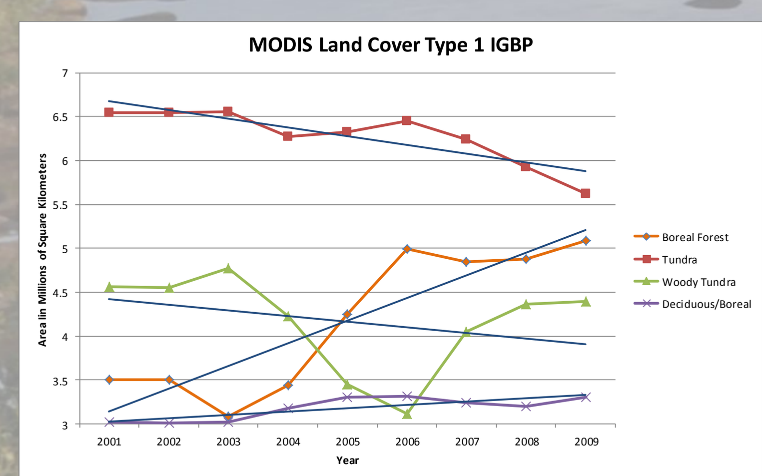
SPOT- First, North American SPOT Vegetation images were derived from SPOT Vegetation Partner, VITO. They were imported from HDF format to IDRISI Raster format; and then converted from 10-day composites to maximum of 30- day composites.

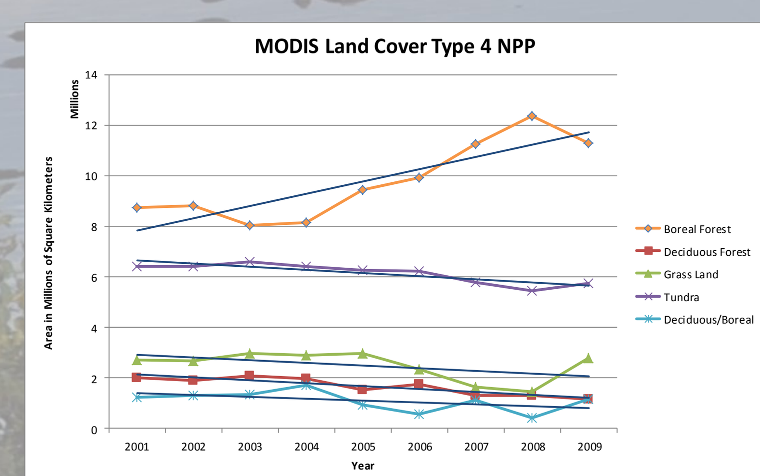
After applying geometric corrections, such as changing reference system from planer to latitude/longitude, and reference units from meter to degrees, the images were windowed-out to Canada. Windowed-out images were further masked out to our research area, Quebec and Newfoundland & Labrador.

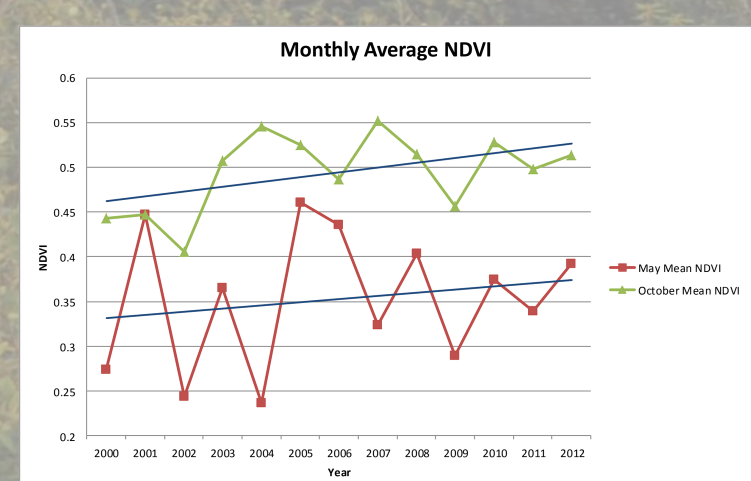
The datasets were originally saved as eight byte per pixel values, between 0 and 255 by VETO. Using the formula PV = (0.004 * DN) - 0.1, i.e. scale = 0.004 and offset = -0.1, the real dimension of NDVI index values were derived, which ranges between -0.096 (DN=1) and 0.92 (DN=255) [the reference for the equation from NASA: http://landval.gsfc.nasa.gov/pdf/SPOT_VGT_NDVI_subsets.pdf]

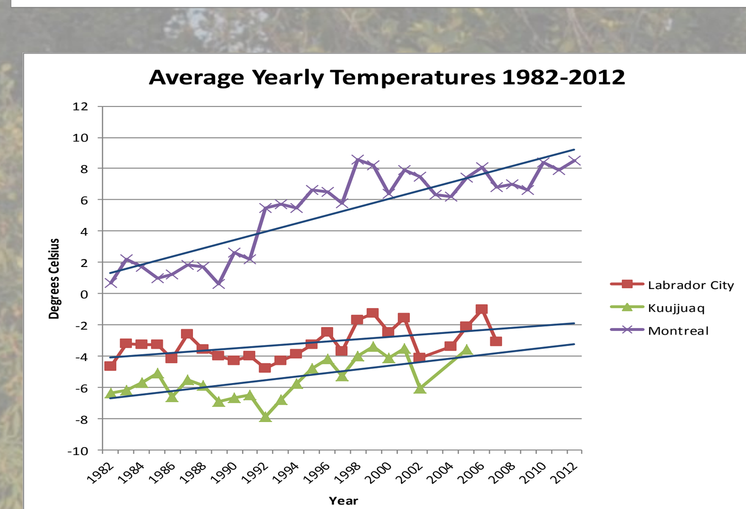
Next, group files for May and October were created, and with the help of Profile Generator in IDRISI, Time Series Analysis was applied to summarize the mean of each image.



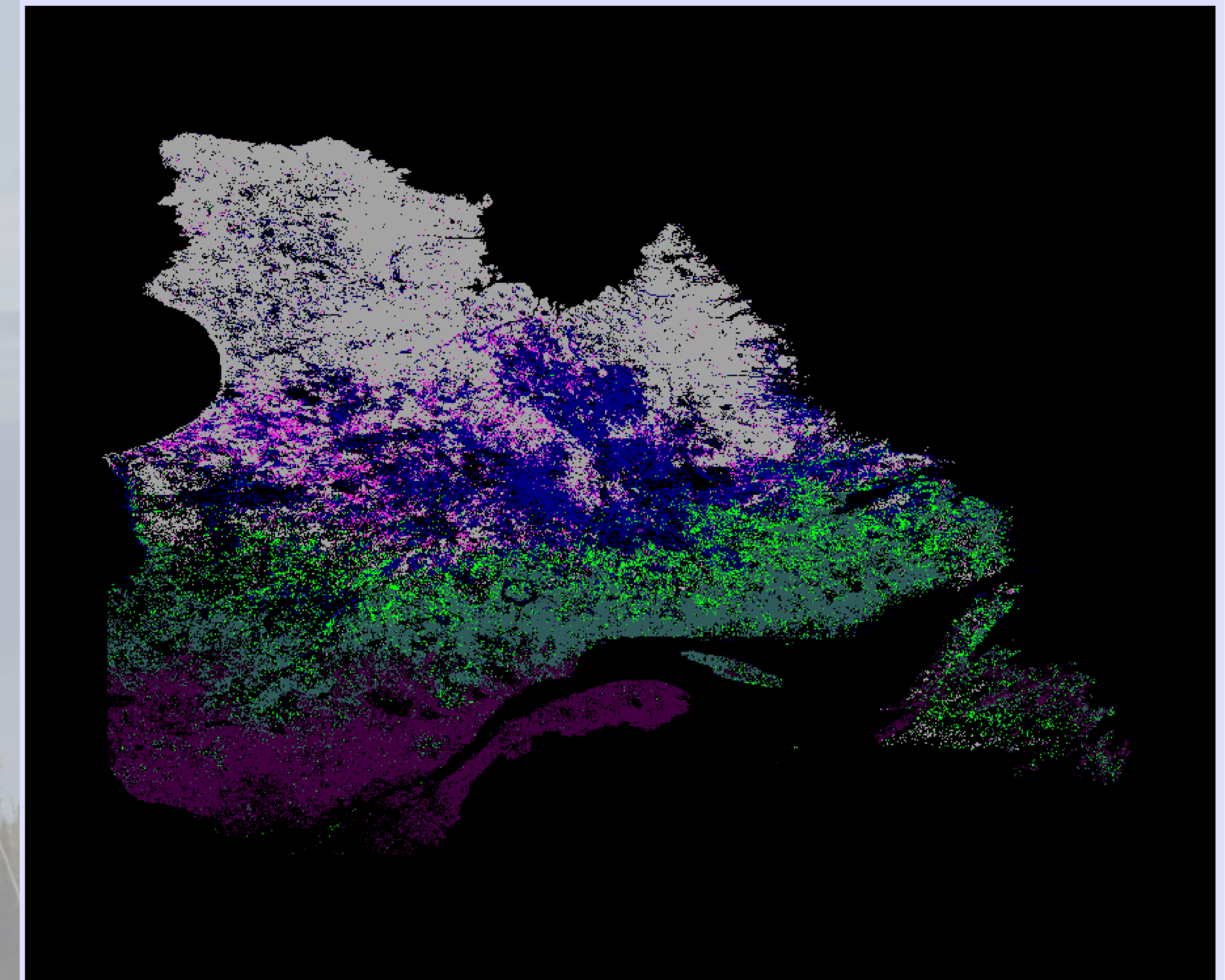




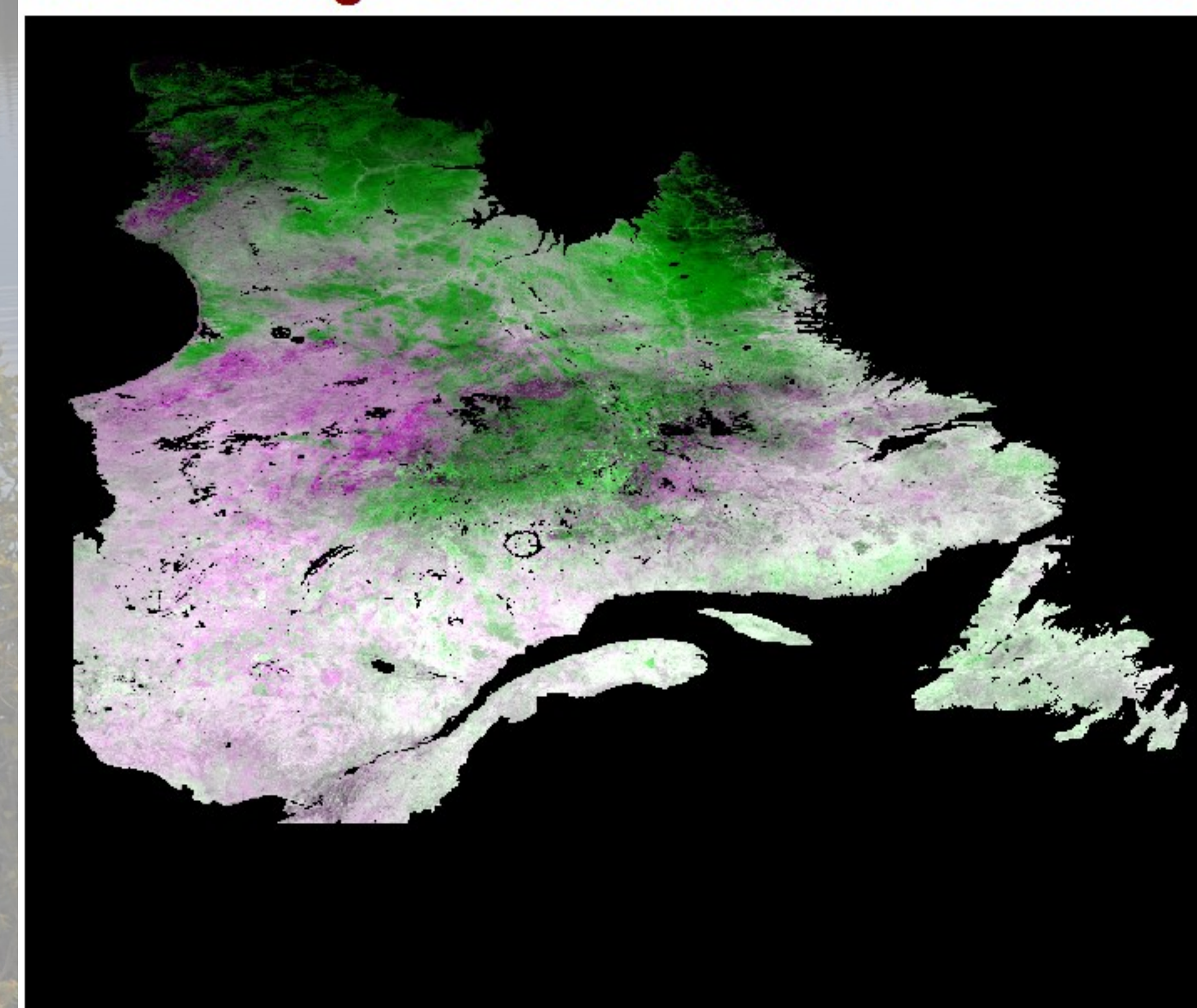




Areas of Change: 2001 - 2009



NDVI Change Detection 2000-2012 October



Results

These nine temporal scenes (left) are a time series of October NDVI data overlaid by the maximum extent of the boreal forest for the years of 2001-2009. In the bottom center of the page are five graphs showing the change in MODIS land cover type 1 (IGBP), MODIS land cover type 4 (NPP), SPOT NDVI data, the changing temperatures over 31 years and temperature over the nine years correlated with the MODIS data. There was a wide variety of change in all land covers, NDVI and temperature. Each data set is numerically summarized below:

MODIS land cover type 1

	Boreal Forest	Tundra	Woody Tundra	Deciduous/Boreal	Deciduous Forest
Total Change (SQ KM)	1590285	-921497.5	-171855	283010	-23482.5
Annual Change Mean (SQ KM)	259083.9167	-99572.58333	-63920.33333	38356.54167	-63361.125
Min (SQ KM)	3084560	5620817.5	3113965	3003910	188910
Max (SQ KM)	5089997.5	6550482.5	4770577.5	3310302.5	231810

MODIS land cover type 4

	Boreal Forest	Deciduous Forest	Grass Land	Tundra	Deciduous/Boreal
Total Change (SQ KM)	2562425	-824427.5	71035	-669860	-42390
Annual Change Mean (SQ KM)	483998.5417	-114158.375	-108971.5417	-123130.5417	-73858.25
Min	8041632.5	1179735	1461450	5447727.5	426260
Max	12343282.5	2076700	2967107.5	6600062.5	1723275

SPOT NDVI 30 day maximum composite

	May NDVI	October NDVI
Total Change (SQ KM)	0.118	0.07
Annual Change Mean (SQ KM)	0.00362088	0.134160962
Max	0.461	0.552
Min	0.236	0.406

Average yearly temperature

	Labrador City	Kuujjuaq	Montreal
Total Change (Celsius)	1.6	2.8	7.8
Annual Change Mean (Celsius)	0.074415584	0.10805195	0.26350806
Max	-1	-3.4	8.6
Min	-4.8	-7.9	0.6

Conclusions

As temperatures warmed over the study period, there was an expected, yet alarming change in land cover and NDVI in Quebec, Newfoundland and Labrador. From 2001-2009 the area of boreal forest grew over 1.5 million square kilometers and annually grew nearly 260,000 square kilometers. Most of the initial growth was located within the forest, by filling in area that was classified as 'woody tundra' as can be seen in the land cover type 1 graph below. Mid-way through the study the boreal forest began to grow outward towards the tundra and the deciduous forest. The expansion of the boreal forest is reflected by the steady decrease in area of tundra land cover over the last five years.

In conjunction with the expanding boreal forest, NDVI consistently rose over the twelve year study period. The change in May, at the beginning of the growing season, had more variance year to year due to deciduous forest's flux in NDVI; while the NDVI in October consistently rose from year to year. October is a more accurate depiction of change in NDVI because in October the deciduous forest's leaves have changed and in high latitudes where tundra is located, there is not enough light to photosynthesize efficiently. This emphasizes boreal forest's NDVI since needle leaf vegetation has the strongest NDVI in October.

Overlaying October's NDVI with the boreal forest land cover accentuates the overall change in land cover and NDVI from the increase in temperature.

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Data Sources: MODIS– NASA, SPOT– VITO, Temperature– Weatheroffice.gc.ca, Background– Dave Santillo