Approaches to Monitoring Northern Vegetation Change with Satellite Remote Sensing

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Why Monitor Vegetation Change?

• Climate change and feedback
  – Surface albedo
  – Vegetation-atmosphere gas exchange
  – Permafrost

• Ecosystem status and trends
  – Wildlife
Northern Vegetation Change

- Global temperatures have increased 0.6 degrees C since the start of the industrial revolution and Arctic temperatures have increased almost twice that rate (ACIA, 2004)
- Landscape photography
  - Increased shubiness (Sturm et al., 2001)
- Experimental warming
  - Increased vascular plant growth and a decrease in lichen and bryophyte abundance (Cornelissen et al., 2001; Hollister et al., 2005)
- Satellite NDVI time-series analyses
  - Northern ‘greening’ (Myneni et al., 1997; Pouliot et al., 2008)
- Few direct measurements of long-term northern vegetation change exist
Remote Sensing of Vegetation

- Red: chlorophyll absorption
- NIR: leaf volume scattering
- Normalized Difference Vegetation Index as proxy for gross photosynthesis
  \[ \text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}} \]
- Both Red and NIR bands are affected by shadow at canopy scale
Approaches

- Robust trend detection
  - Changes in NDVI

- Spectral mixture analysis
  - Changes in vegetation composition

- Canopy reflectance modeling
  - Changes in vegetation composition and structure
Commonly Used Remote Sensing Data archived at CCRS

- **Landsat**
  - 30m resolution
  - 16 day revisit time
  - 185 km x 185 km per scene

- **AVHRR and SPOT VGT**
  - 1 km resolution
  - Daily revisit
  - National coverage
Baseline Vegetation Information

Circa-2000 Land Cover of Northern Canada from Landsat

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Abstract

This land cover dataset covering Northern Canada has either been derived directly or as a product of product development efforts to address emerging needs specific to the northern regions of the country for the Earth Sciences Sector. This product is not intended to replace current terrestrial land cover products available from federal and provincial government agencies, such as AgriCanada’s AgriCanada Land Cover Database, the Environmental Change Institute’s Northern Ecosystems Change Analysis (NECA) product, and the Canadian Wildlife Habitat Atlas. Instead, this product is intended to assist in the identification of land cover classes at the coarsest possible scale (e.g., 30 meters) to support the development of higher resolution products. The major data sources used in the development of this product include: 1) 2000-2002 Landsat Thematic Mapper (TM) imagery, 2) 2000-2002 Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery, and 3) 2000-2002 Polar Ortho-Colour (POC) imagery. The product was developed in collaboration with the Earth Sciences Sector and the Canadian Wildlife Habitat Atlas. The product is available for download at http://geogratis.cgdi.gc.ca/

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Legend

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Canada

Natural Resources Canada

Resources naturelles Canada
Hollister et al. (2005) proposed that the long-term effect of increased temperature on northern vegetation was the result of numerous short-term physiological responses plus changes in recruitment.
Recent (1986-2006) vegetation-specific NDVI trends in Northern Canada from Satellite Data

Solve for percent change in lichen ($\Delta L$), bare ($\Delta B$) and vascular ($\Delta V$) such that:

$$0 = \pm \Delta L + \pm \Delta B + \pm \Delta V$$

where:

$$\Delta L = Lichen \, NDVI \, endmember* \pm \text{one standard deviation} = 0.289 \pm 0.021$$

$$\Delta B = Bare \, NDVI \, endmember* \pm \text{one standard deviation} = 0.228 \pm 0.057$$

$$\Delta V = Vascular \, NDVI \, endmember* \pm \text{one standard deviation} = 0.563 \pm 0.022$$

*from Olthof and Latifovic, 2007
Treeline Changes

NDVI, band 2 and band 1 AVHRR trend slopes as R,G,B used to classify compositional change.

Canopy reflectance modeling simulation

-1SD  |  Mean  |  +1SD

Grass  |  ![Image of Grass](image1.png)  |  ![Image of Grass](image2.png)  |  ![Image of Grass](image3.png)
Lichen  |  ![Image of Lichen](image4.png)  |  ![Image of Lichen](image5.png)  |  ![Image of Lichen](image6.png)
Bare    |  ![Image of Bare](image7.png)    |  ![Image of Bare](image8.png)    |  ![Image of Bare](image9.png)
Shrub   |  ![Image of Shrub](image10.png)  |  ![Image of Shrub](image11.png)  |  ![Image of Shrub](image12.png)
Conifer |  ![Image of Conifer](image13.png) |  ![Image of Conifer](image14.png) |  ![Image of Conifer](image15.png)

- Increase
- Decrease
- No change
Summary of Vegetation Changes

• Short-term temperature anomalies enhance vascular productivity and suppress non-vascular productivity in humid northern regions
  – Long-term vegetation composition due to numerous short-term effects
• In the longer-term, productivity is increasing across all northern vegetation types with vascular vegetation increasing at a higher rate than non-vascular
  – Spectral mixture analysis suggests non-vascular replacement with vascular
• Treeline changes are consistent with tundra changes
  – Canopy reflectance modeling suggests increasing shrub and grass offsetting decreasing bare. Conifer response is variable, increasing in closure in some areas and decreasing in others