Greening dynamics and shrubland extent from remote sensing using NDVI Index: case study of the George River basin (Nunavik, Canada)

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Background

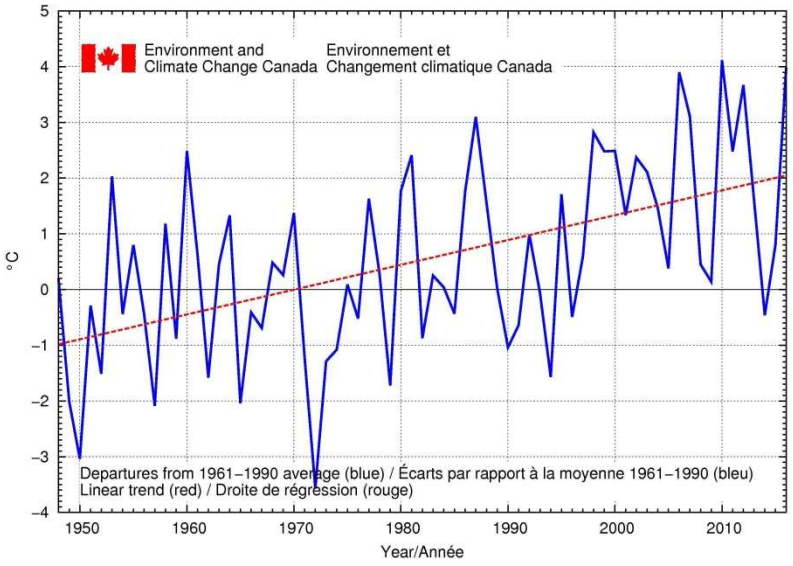
❖ Scientific context

- Rapidly increasing temperatures in the Arctic and decreasing snow cover duration have led to **longer growing seasons** affecting vegetation dynamics (treeline, shrubs advancing, ...).
- Arctic greening trends are well documented (Fraser et al., 2011; Tremblay et al., 2012) and this **knowledge is essential** for understanding how climate and environmental change **impact ecosystems, hydrology** (evapotranspiration), **and local communities.**
- **Remote sensing** offers a unique tool for estimating the high latitude vegetation evolution in the long-term, i.e. the **Landsat** archive since the 80's (Ju and Masek, 2016) at consistent resolution (15-30m).
- **Need** for development and testing of **new methods** from spectral indices to quantify vegetation species temporal/spatial evolution.

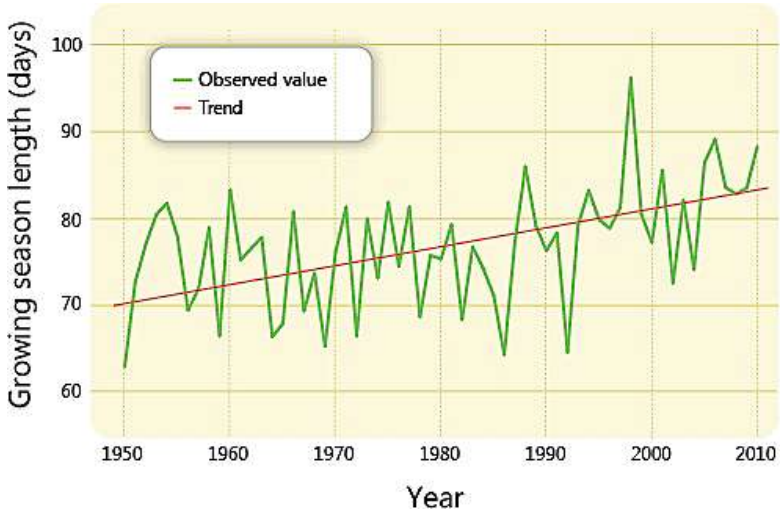
Background

❖ Climate trends

- Winter Canadian temperatures, long-term-trend 1948-2016



- Growing season, long-term-trend 1950-2010 (Natural Resources Canada)



(all national statistics including Nunavik region)

Motivation

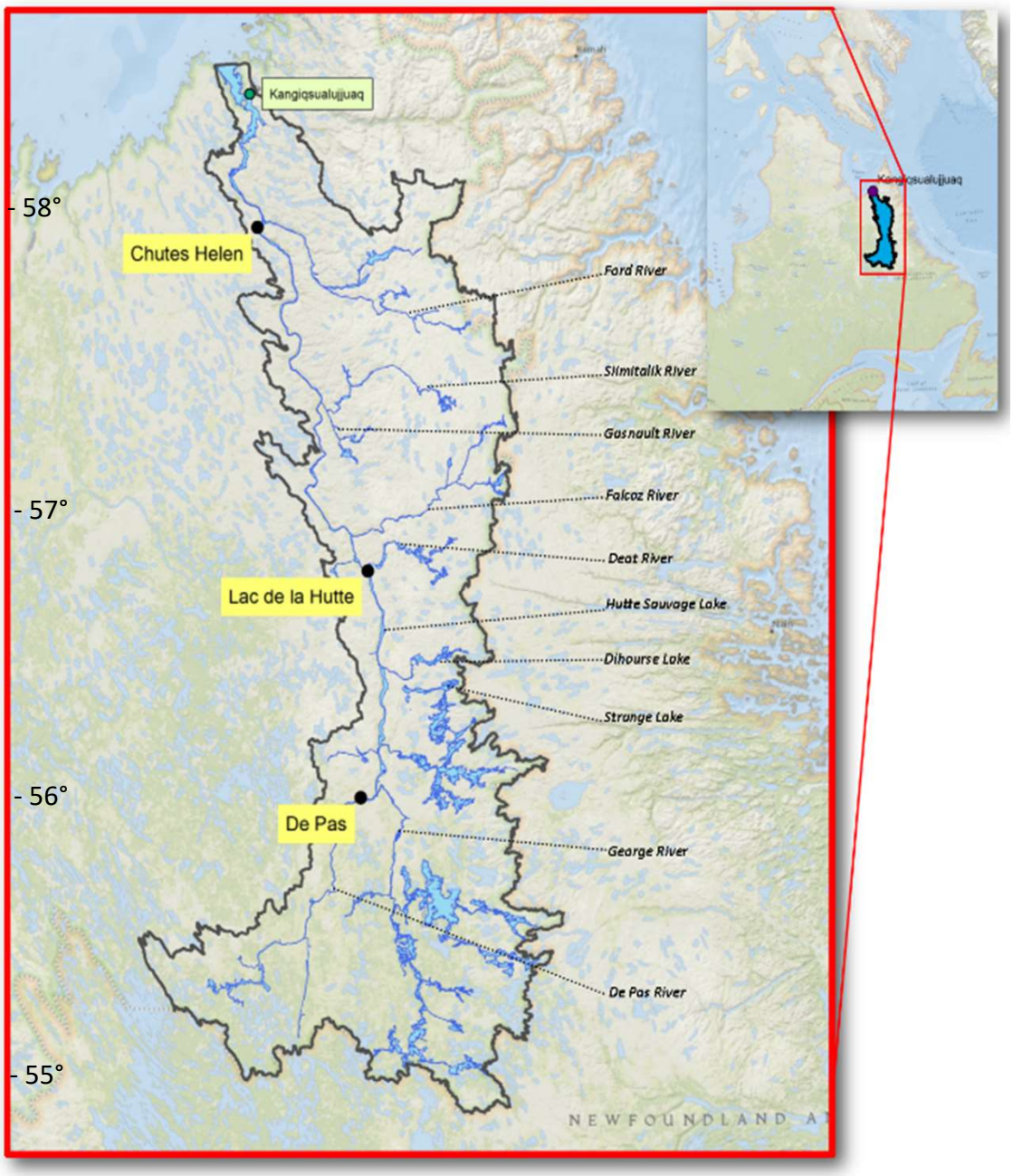
❖ Project objectives

- **Estimate the plant species dynamics** over a 30-year time period (1985-2015) and track their local evolution patterns, by means of in situ observations and optical remote sensing.
- **Evaluate the capability of spectral indices** derived from visible and infra-red wavelengths for relations that can be used to quantify vegetation properties, as the Normalized Difference Vegetation Index (**NDVI**).

Kangirsualujjuaq, 1988 and 2008 *(Tremblay et al. 2012)*

Application site

- **George River**
  - Watershed: ~ 42000 km²
  - River: ~ 600km in length
- **Climate**
  Boreal to Arctic:
  450 – 800 mm/y Precipitation
  (~45 % as snow)
- **Vegetation**
  Boreal to Arctic:
  forest (south) to tundra (north)
- **Soils**
  - Precambrian Shield
  - Thin soils over till or bedrock; bedrock outcrops
- **Kangiqsualujjuaq**
  (58° 41’ N, 65° 57’ W)
  - Population : 942 (2016),
  - Youth 0-19 : 395 (2016)



Methodology

❖ **Analysis of the Vegetation Map from the MRNFP** (Québec, 2018):

- Merging of the classification in 5 dominant classes to adjust with the satellite images processing at 30-m resolution.
- Calculation of the centroïd of each shape file to overlap with satellite images ouputs (vegetation indices).

❖ **Remote Sensing data processing**:

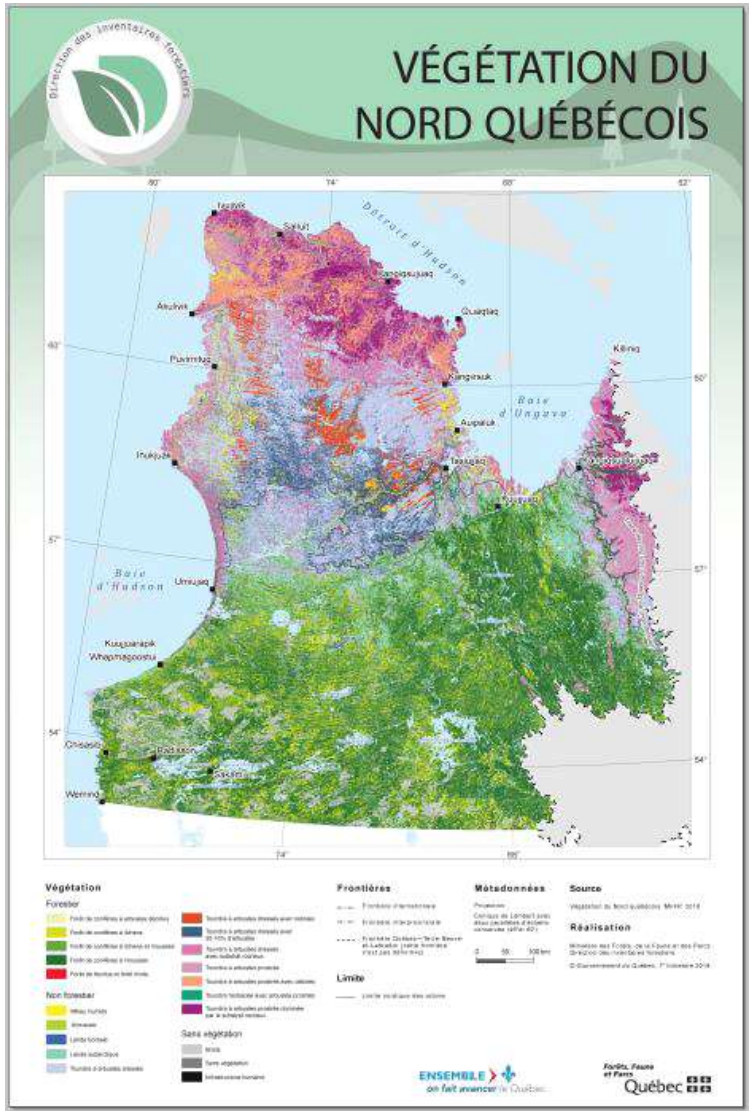
- Landsat Images summer 1985, 2000 and 2015 geometric/atmospheric correction.
- Mosaicking of tiles in surface reflectance at each time-period over the river basin.
- Computation of NDVI = (NIR-R)/(NIR+R) at each period, and absolute/relative difference calculation.

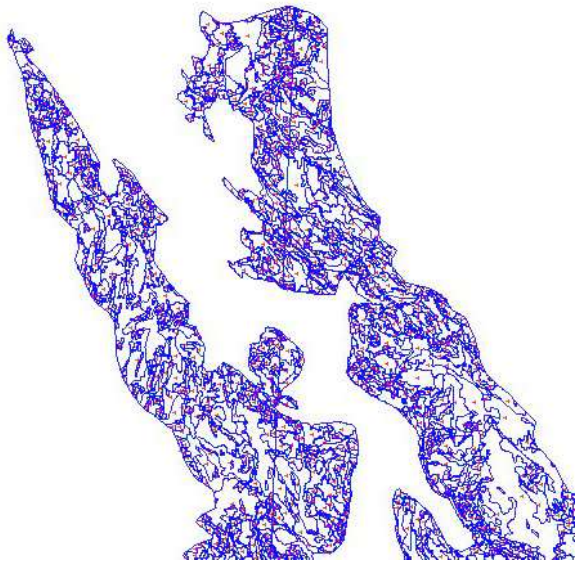
❖ **Field Campaign** (late June – early July 2018):

- Helicopter profiles (GPS camera) over 300 km along the main river, to cover a latitudinal gradient from arctic tundra to boreal forest.
- Sampling on representative sites for different vegetation types under evolution.
- Ground measurements : type characterization, vegetation height, dominant species, signs of disturbance, etc.

Land cover process

1. MRNFP Vegetation Map





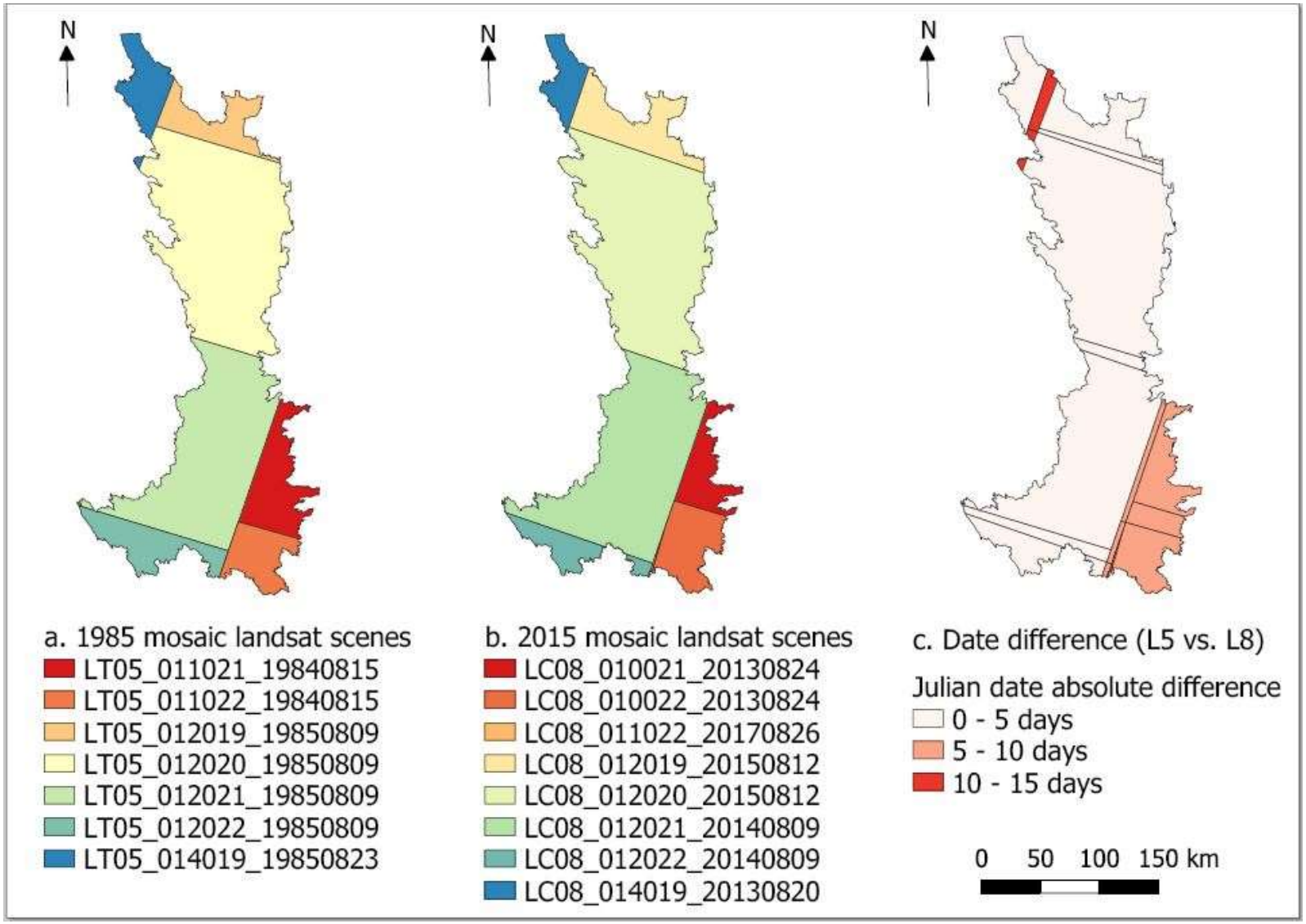
Shape files extraction and centroïd calculation

Vegetation dominant types
Prostate shrub tundra
Erect shrub tundra
Sub-arctic vegetation
Wetlands
Boreal forest

Land cover types

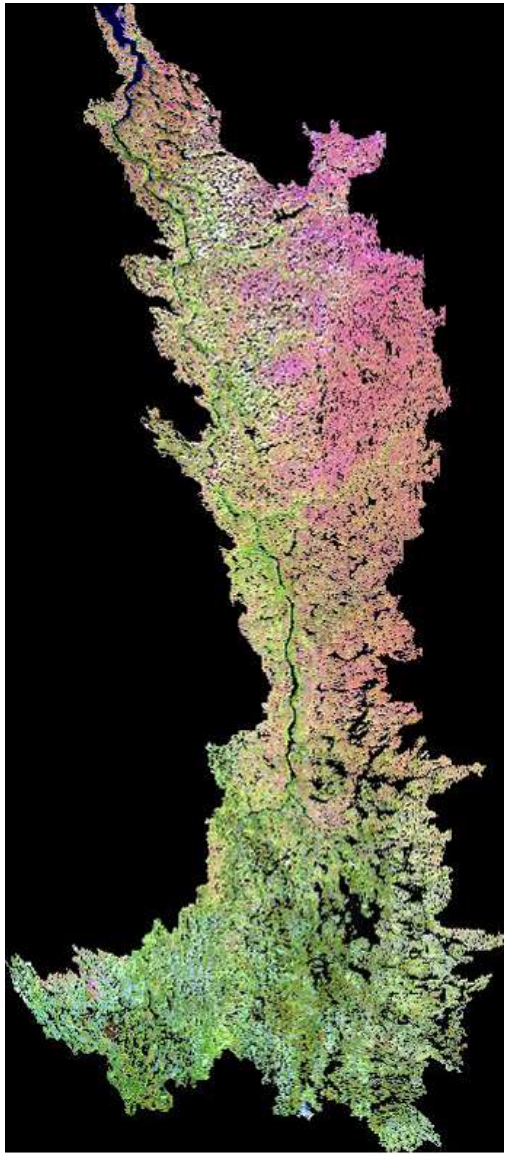
Remote sensing process

2. Landsat database

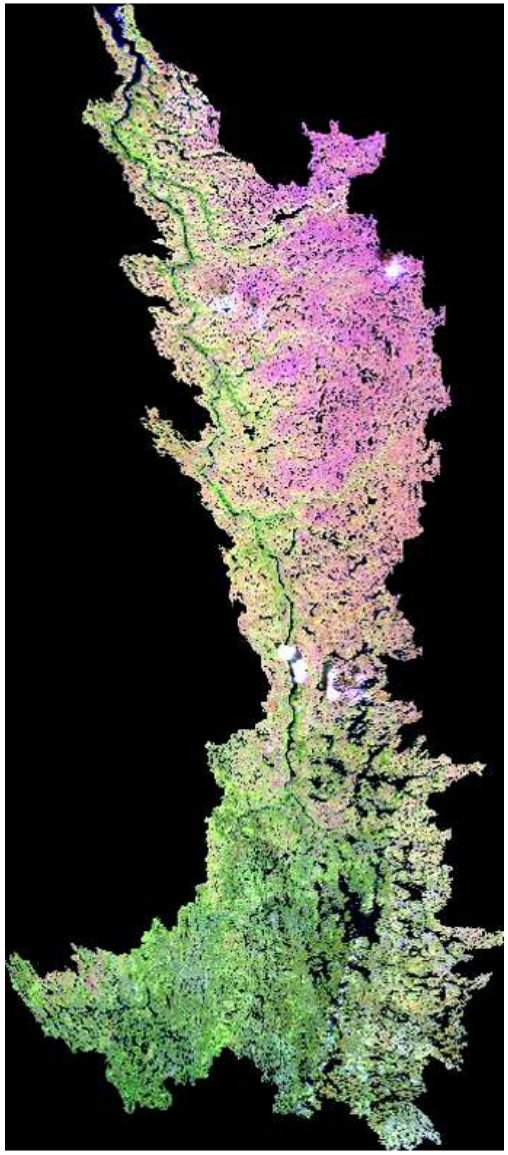


Landsat visible and infrared composite images

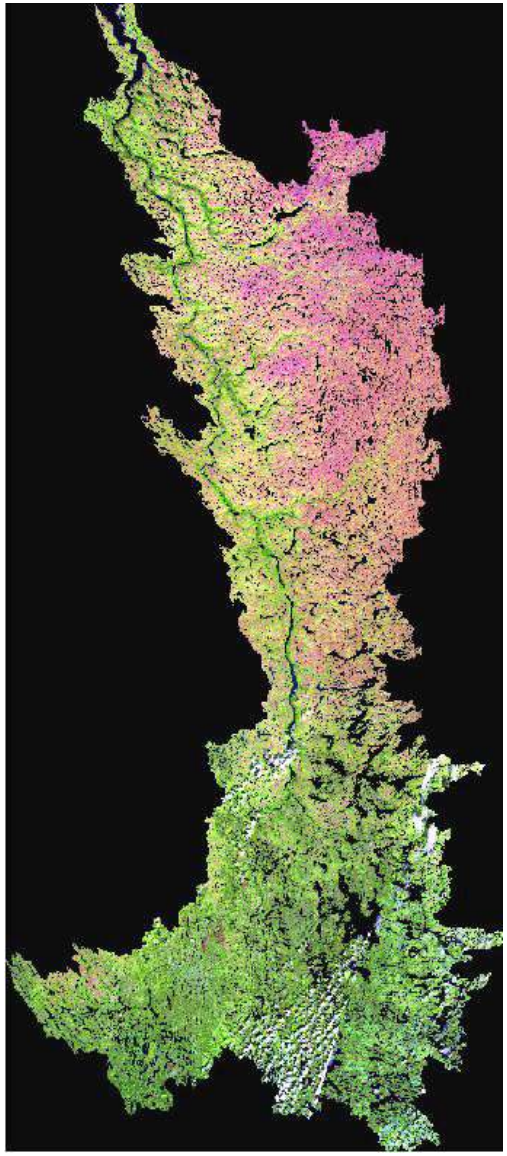
green : dense vegetation, magenta-orange : sparce veg, dark : water bodies



Landsat-5 1985 mosaic

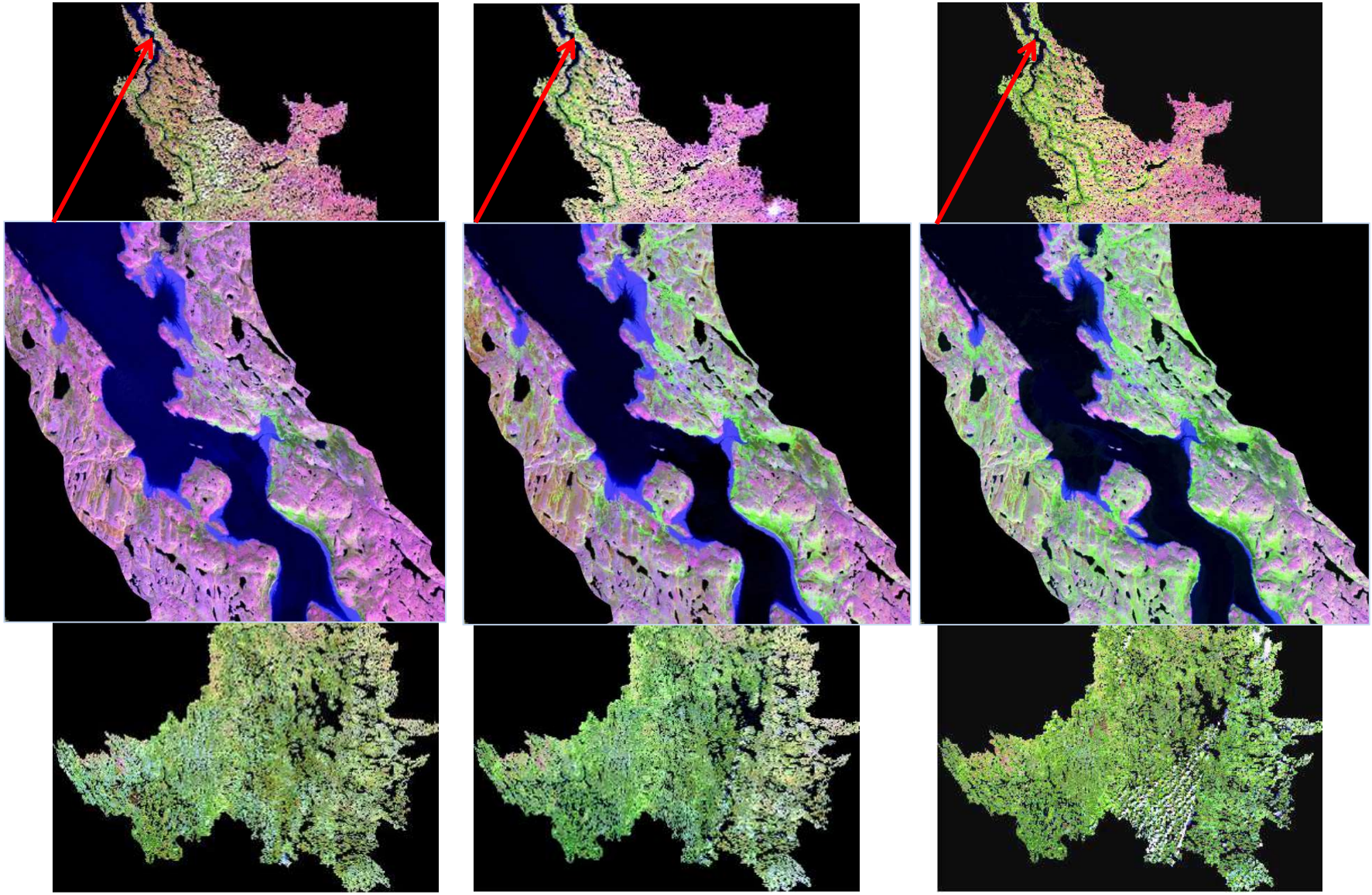


Landsat-7 2000 mosaic



Landsat-8 2015 mosaic

Greening trend: example of the Kangiqsualujuuaq village area
(arctic and subarctic vegetation)

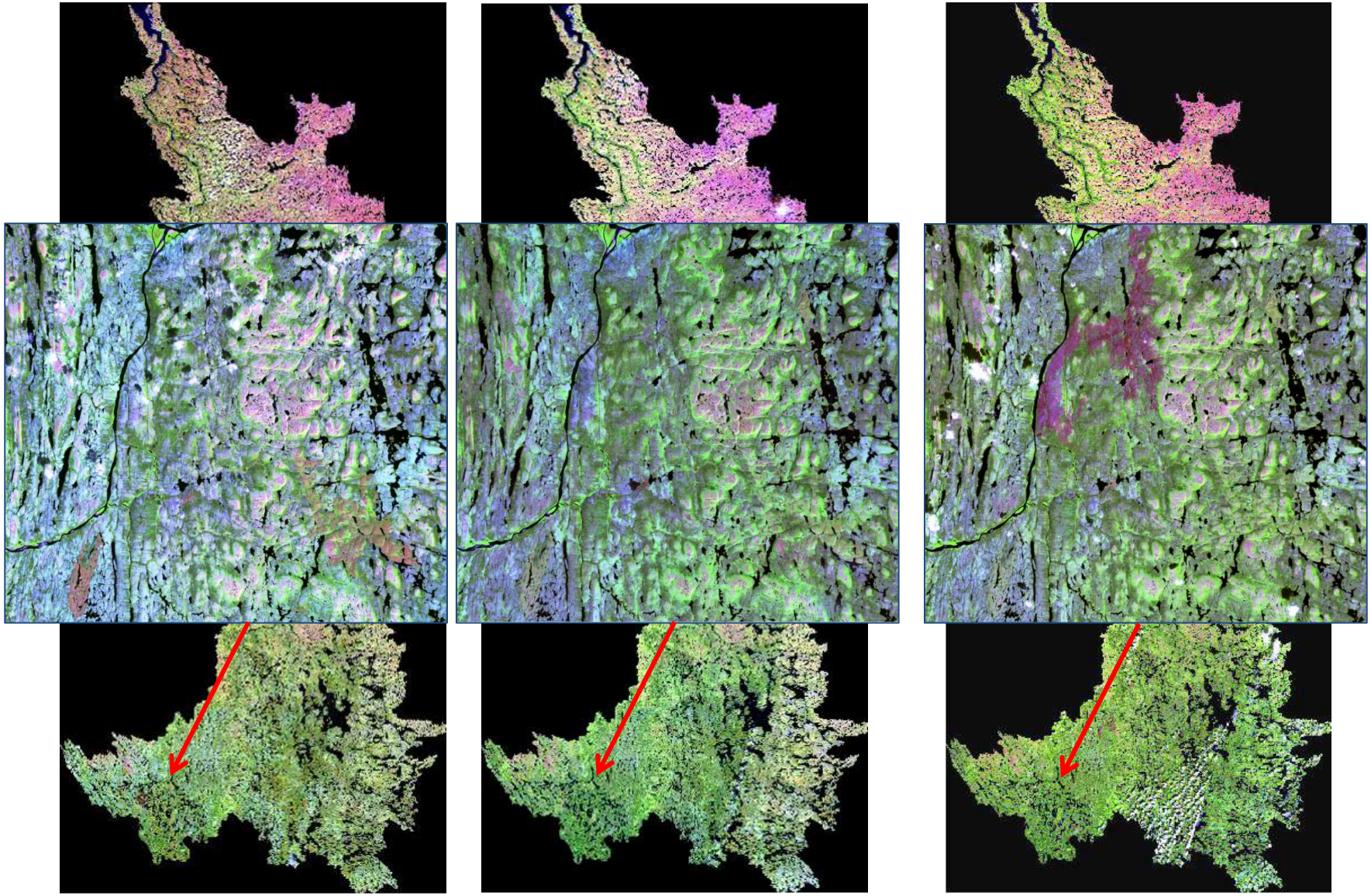


Landsat-5 1985 mosaic

Landsat-7 2000 mosaic

Landsat-8 2015 mosaic

Browning trend: example of the Schefferville region with fires and human deforestation *(boreal forest)*



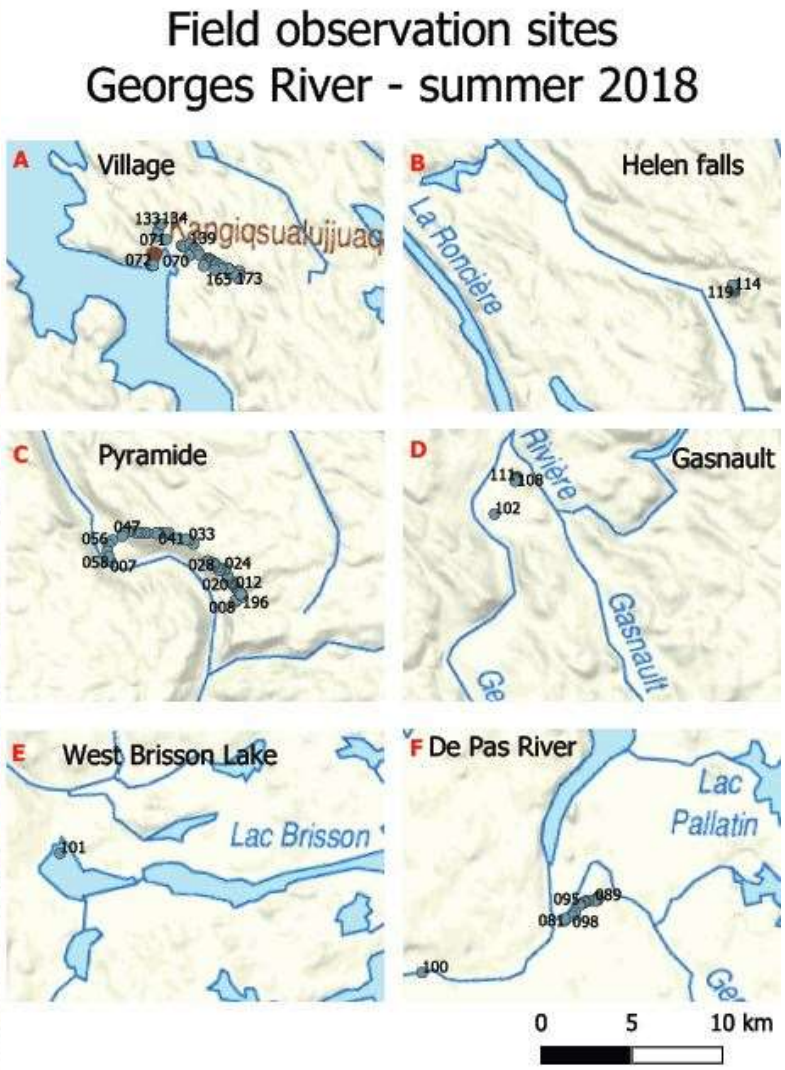
Landsat-5 1985 mosaic

Landsat-7 2000 mosaic

Landsat-8 2015 mosaic

Field Campaign

In-situ measurements



Photograph transects by helicopter

Field Campaign

A

B

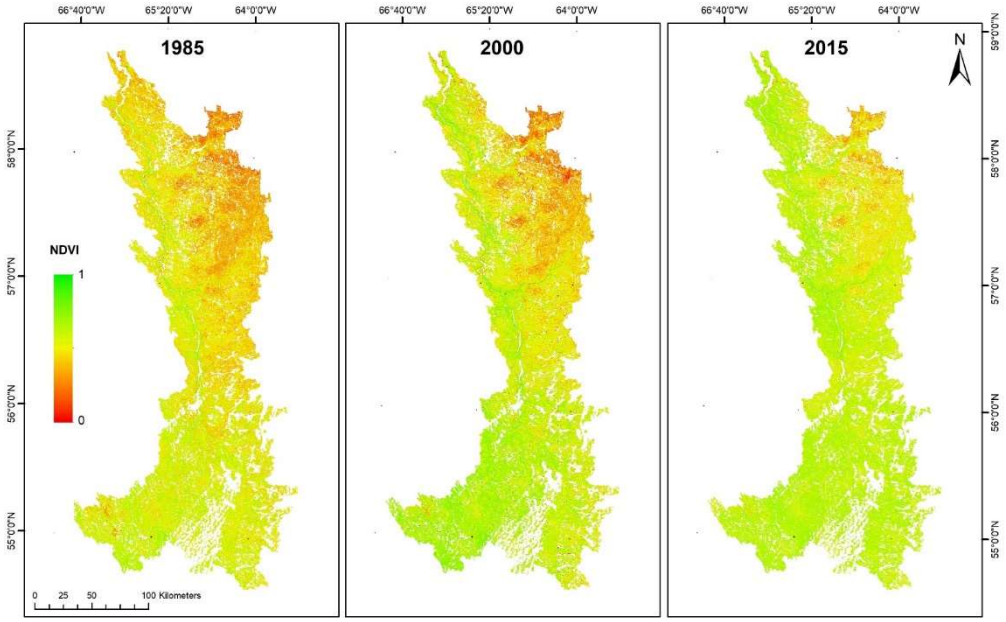
C

D

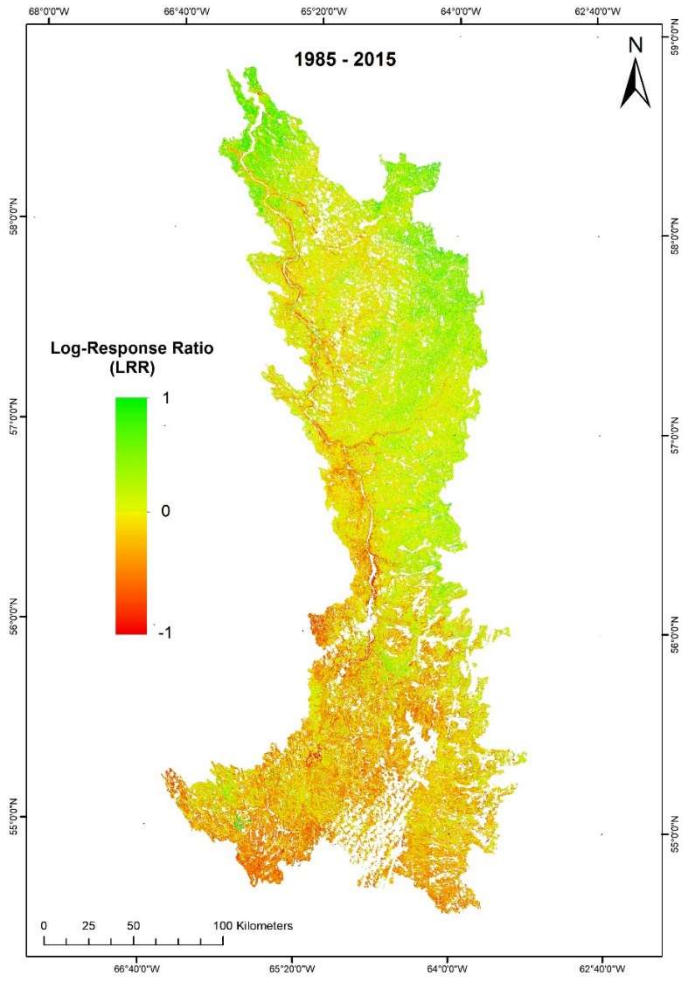
A) Lichen-spruce woodland (*Cladonia* sp.)
B) Sparse moss-spruce, shrubs and lichens (*Stereocaulon* sp.)
C) Black spruce (green), larch (without needles), shrubs and lichens
D) Decideous shrubs, herbs, mosses, lichens and spruce recruits (green)

Results

Landsat NDVI calculation and Log-Ratio response (LRR)

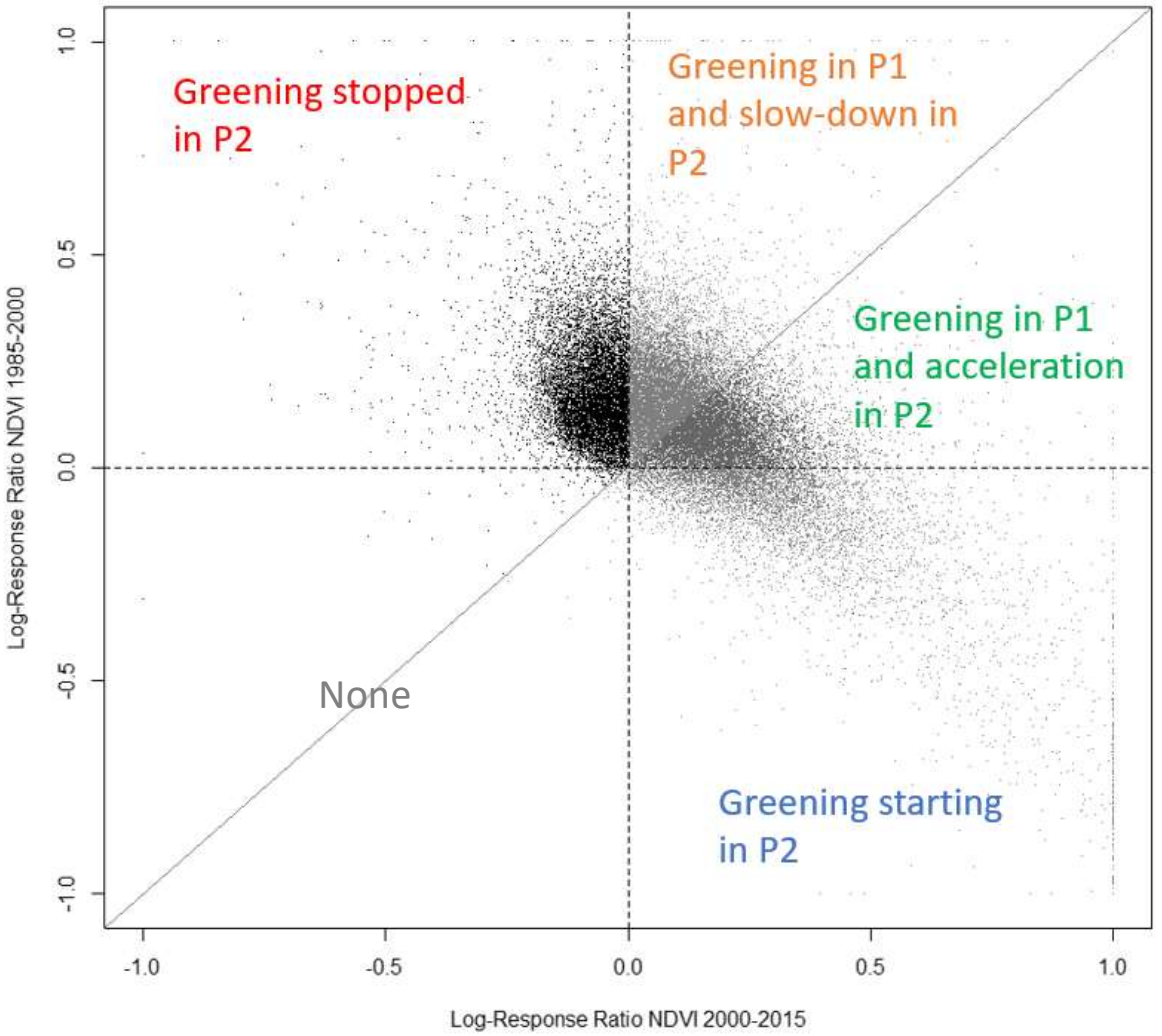


*1st time period (**P1**)* *2sd time period (**P2**)*



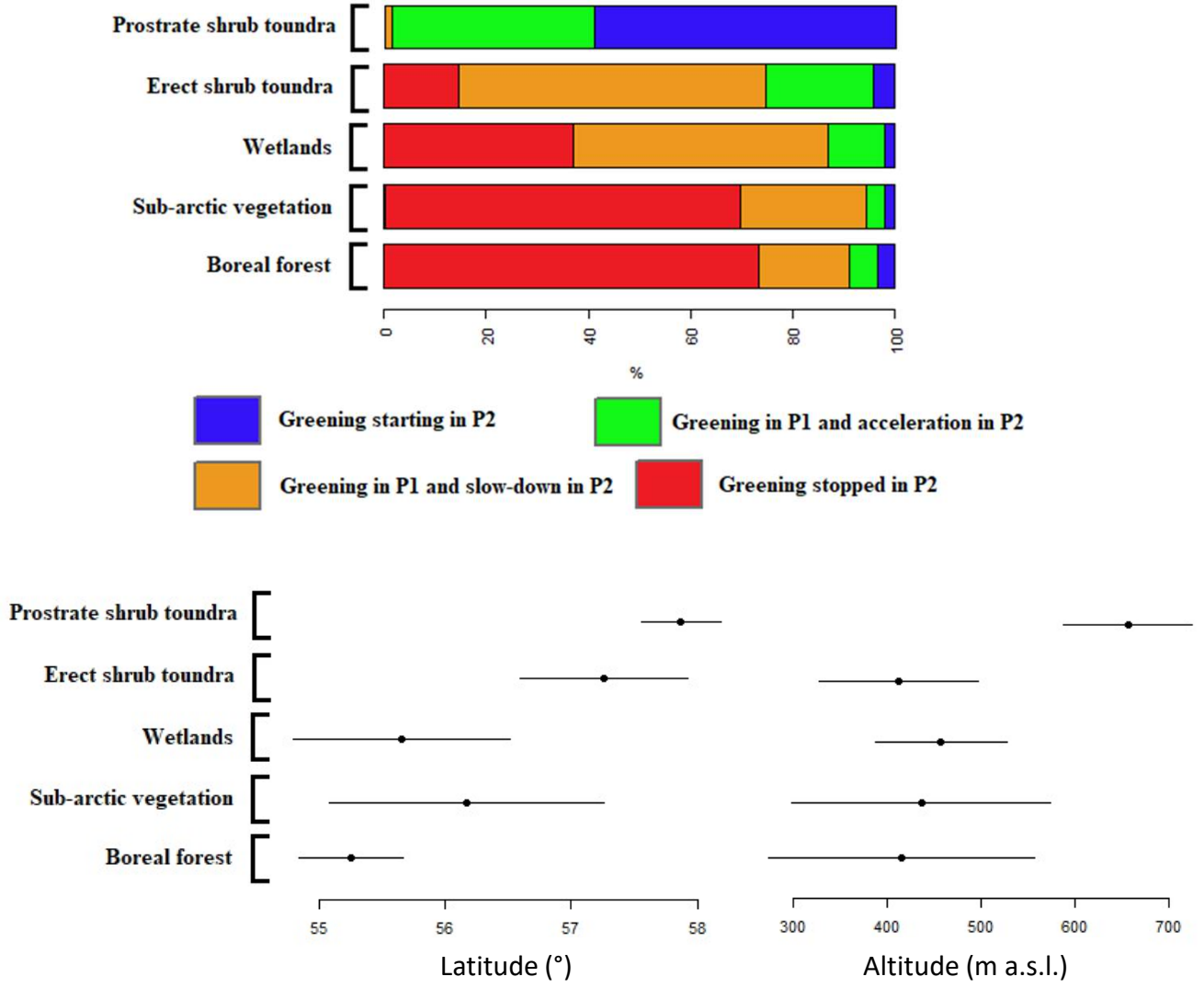
Landsat 30-year NDVI time periods evolution and LRR comparison.

Results



Comparison between LRR of Period 1 (1985-2000) and LRR of Period 2 (2000-2015): four different greening behavior.

Results



Statistical distribution of the four greening trends on the main land use classes and relation with topographic parameters.

Work under progress

Recent warming in Nunavik:
more shrubs, more trees, less berries?

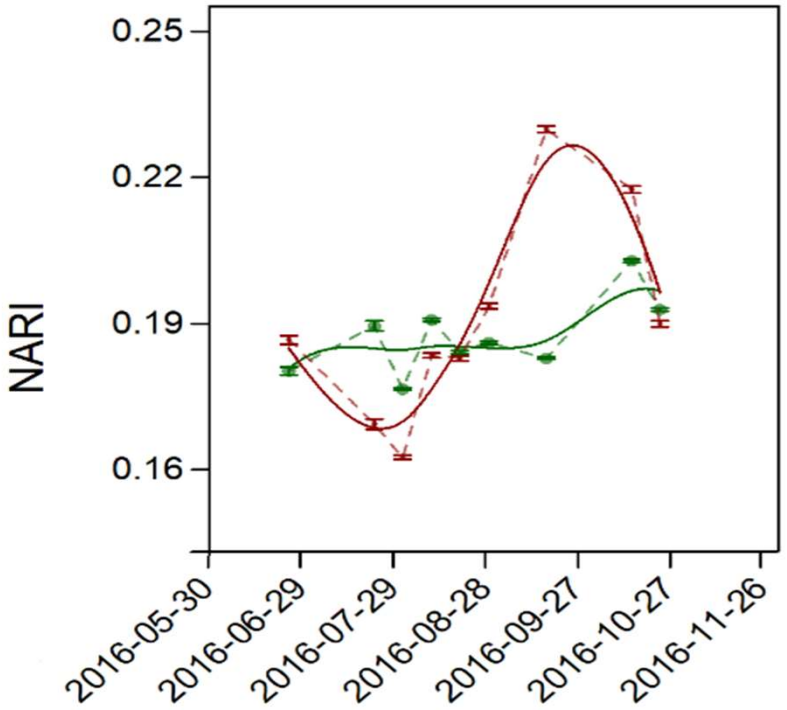
Work under progress

- Application of newly developed Normalized Anthocyanins Reflectance Index (**NARI**) using Sentinel-2 red-edge bands (689 - 719 µm) to map **Ericaceous-dominated shrublands**

- NARI can help understanding of the Ericaceous shrubs contribution to the **greening dynamics** and its impact on the **local communities'** resources (particularly **berries**)

French Alps case study :

NARI increasing values in spring and fall distinguishes contribution of Shrublands from Grasslands.



(*A. Bayle et al., Remote Sensing 2019*)

Conclusion

- Remote sensing results reveal a **clear greening trend** at the river basin scale over a 30-year time period, 1985-2015.

- Although greening was observed across the whole latitudinal gradient, the relative NDVI increase is **stronger** on the northern half (and higher elevation) of the study area, mostly covered with **tundra and subarctic vegetation.**

- Four different greening trends over two time periods P1 & P2 indicate: (i) a **major NDVI increase** for **sparsely vegetated areas** (P1 then P2), and (ii) **the levelling-off** of greening/growth for **boreal forest** since 2000 (P2).

- **Need** of more advanced algorithm (NARI) using sensor with finer spectral resolution (Sentinel-2) **to avoid confusion** between ericaceous shrubs (berry producing) and other vegetation covers.

Thanks for your attention !

(Photo J. Housset, 2018)

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