PPS Arctic

The dynamics of the forest lines (birch and pine) in northern Norway and Kola Peninsula (Russia) revealed by spectral unmixing and spectral angle mapping of multi-temporal satellite images in the period 1972-2008

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Mathisen, I.E. and Hansen, F.

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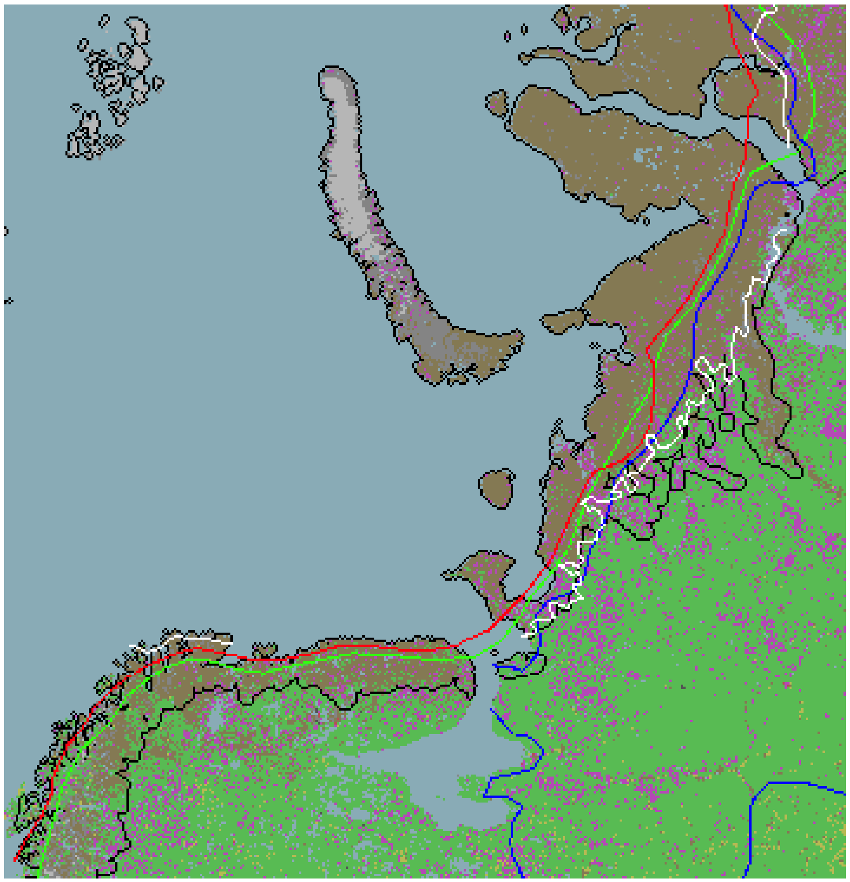
Circumpolar Arctic Vegetation Map (CAVM, 2003) to the northernmost limit of boreal forests



- Red, green and blue lines: birch, evergreen conifer and larch treelines from Hustich (1983). White line: treeline adopted by the CAVM (CAVM team 2003).

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Objectives

- Detect the altitidunal forest-line for birch in Abisko area in Sweden) and Inner part of Troms using spectral unmixing and related methods
- Detect the northern forest-lines for birch and pine (Porsanger, Nordkyn, Pasvik and Kola peninsula) using using spectral unmixing and related methods

Methods: Performing Linear Spectral Unmixing and SAM Classification

- Use **Linear Spectral Unmixing** to determine the relative abundance of materials that are depicted in multispectral or hyperspectral imagery based on the materials' spectral characteristics. The reflectance at each pixel of the image is assumed to be a linear combination of the reflectance of each material (or endmember) present within the pixel. Spectral unmixing results are highly dependent on the input endmembers.

- **Spectral Angle Mapper (SAM)** is a physically-based spectral classification that uses an *n*-D angle to match pixels to reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra and treating them as vectors in a space with dimensionality equal to the number of bands. Smaller angles represent closer matches to the reference spectrum.

- **Mixture Tuned Matched Filtering (MTMF)** is useful because it allows f unmixing pixels that are not directly related to the collected end-members; other unmixing techniques require that the analyst account for all the possible end-members in a landscape.

Methods

- **Minimum Noise Transform**
- **Data Dimensionality and Spatial Coherence**
- **Deriving Endmembers**
- **Performing Spectral Angle Mapper Classification, Mixture Tuned Matched Filtering, and Linear Spectral Unmixing**

Methods

- **Minimum Noise Transform**

- The MNF transform is used to determine the inherent dimensionality of image data, to segregate and equalize the noise in the data, and to reduce the computational requirements for subsequent processing.

Methods

- **Data Dimensionality and Spatial Coherence**

- Data dimensionality indicates the number of intrinsic endmembers that the dataset contains, since each linearly independent component adds another dimension to a spectral dataset through mixing. You can determine the data dimensionality in the MNF Eigenvalues plot by finding where the slope of the eigenvalue curve breaks and the values fall to 1.

Spectral Angle Mapper

$$\alpha = \cos^{-1} \frac{\Sigma XY}{\sqrt{\Sigma(X)^2 \, \Sigma(Y)^2}} \qquad \text{Equation 1}$$

α = Angle formed between reference spectrum and image spectrum

X = Image spectrum

Y = Reference spectrum

The SAM value is expressed in radians where minor angle α, represents the major similarity among the curves. The angle α, determined by $\cos^{-1}$, presents a variation anywhere between 0° and 90°. The equation above can also be expressed as cos α (equation 2). In these conditions, the best estimate acquires values close to 1.

$$\cos \alpha = \frac{\Sigma XY}{\sqrt{\Sigma(X)^2 \, \Sigma(Y)^2}} \qquad \text{Equation 2}$$

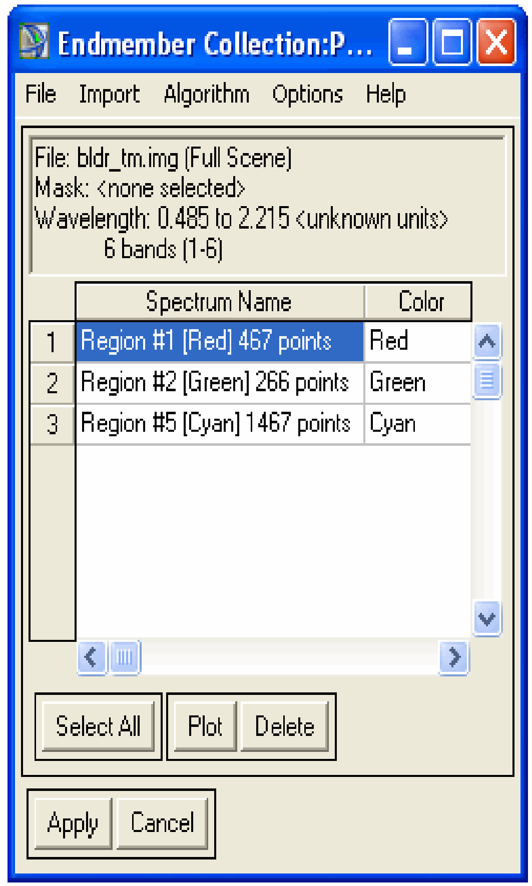
Source: Kruse, F. A., Lefkoff, A. B., Boardman, J. B., Heidebrecht, K. B., Shapiro, A. T.,Barloon, P. J., and Goetz, A. F. H., 1993, “The Spectral Image Processing System (SIPS) - Interactive Visualization and Analysis of Imaging spectrometer Data”. *Remote Sensing of the Environment*, v. 44, p. 145 - 163.

Methods
Picking endmembers is essential

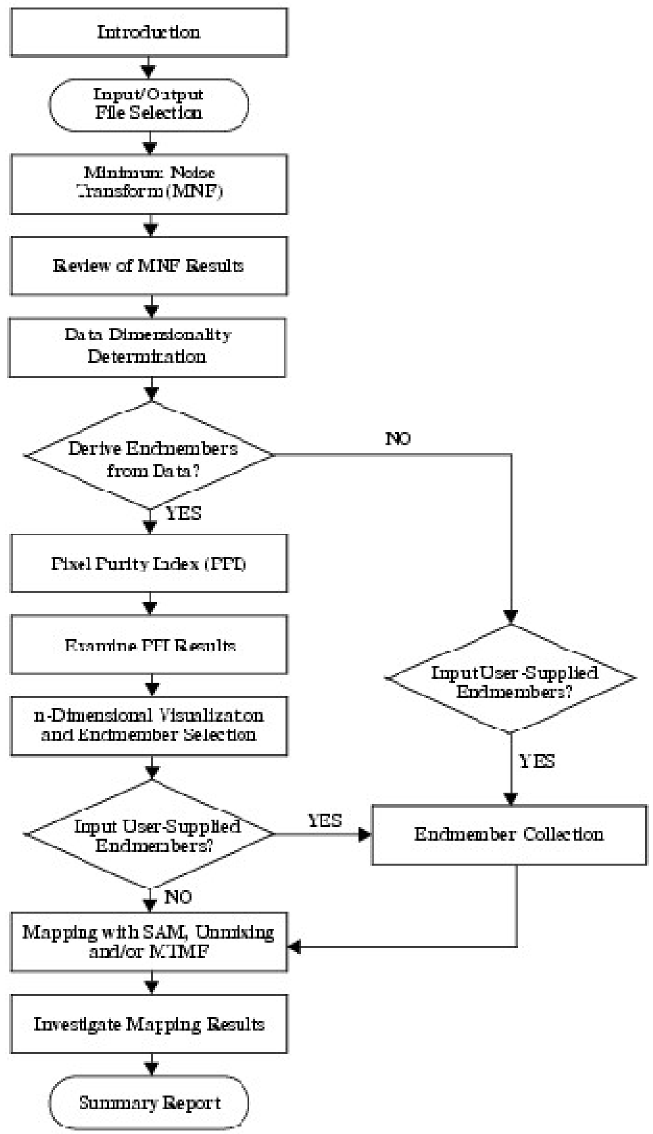
Red=Birch forests

Green=Mountain heaths

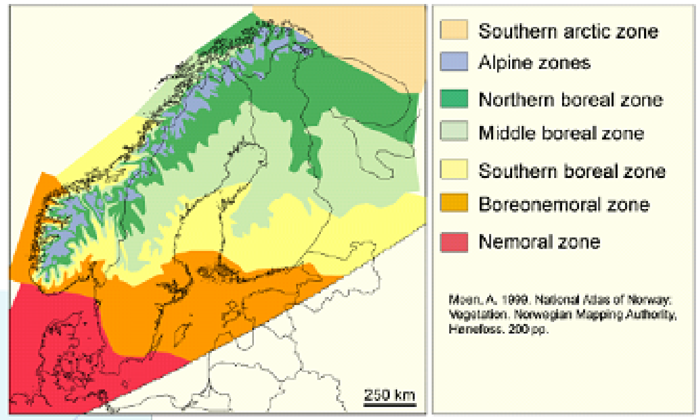
Cyan/Blue=Barrens

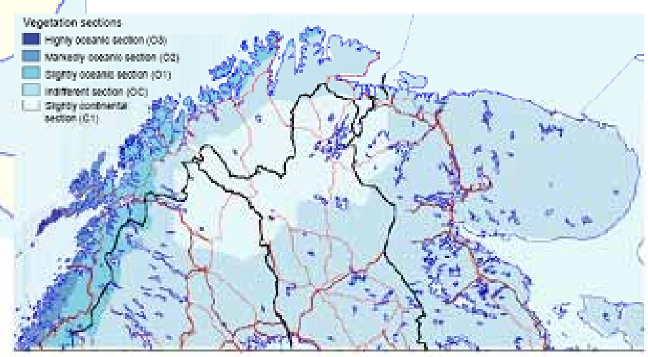


Flow chart spectral unmixing method



The study area





Results

- Change in altitude: Riksgränsen-Njuorajavri-Torneträsk (Sweden)
- Change in latitude: Lakselv-Porsanger-North Cape

Change in altitude: Abisko-Riksgränsen-Njuorajavri-Torneträsk (Sweden)

- Based on Unmixing and SAM methods on a SPOT Image from 2008-08-24 (10 meters spatial resolution)

- Compared with:
- Topographic map/aerial photos 1978-80
- Vegetation map/aerial photos 1978/1982

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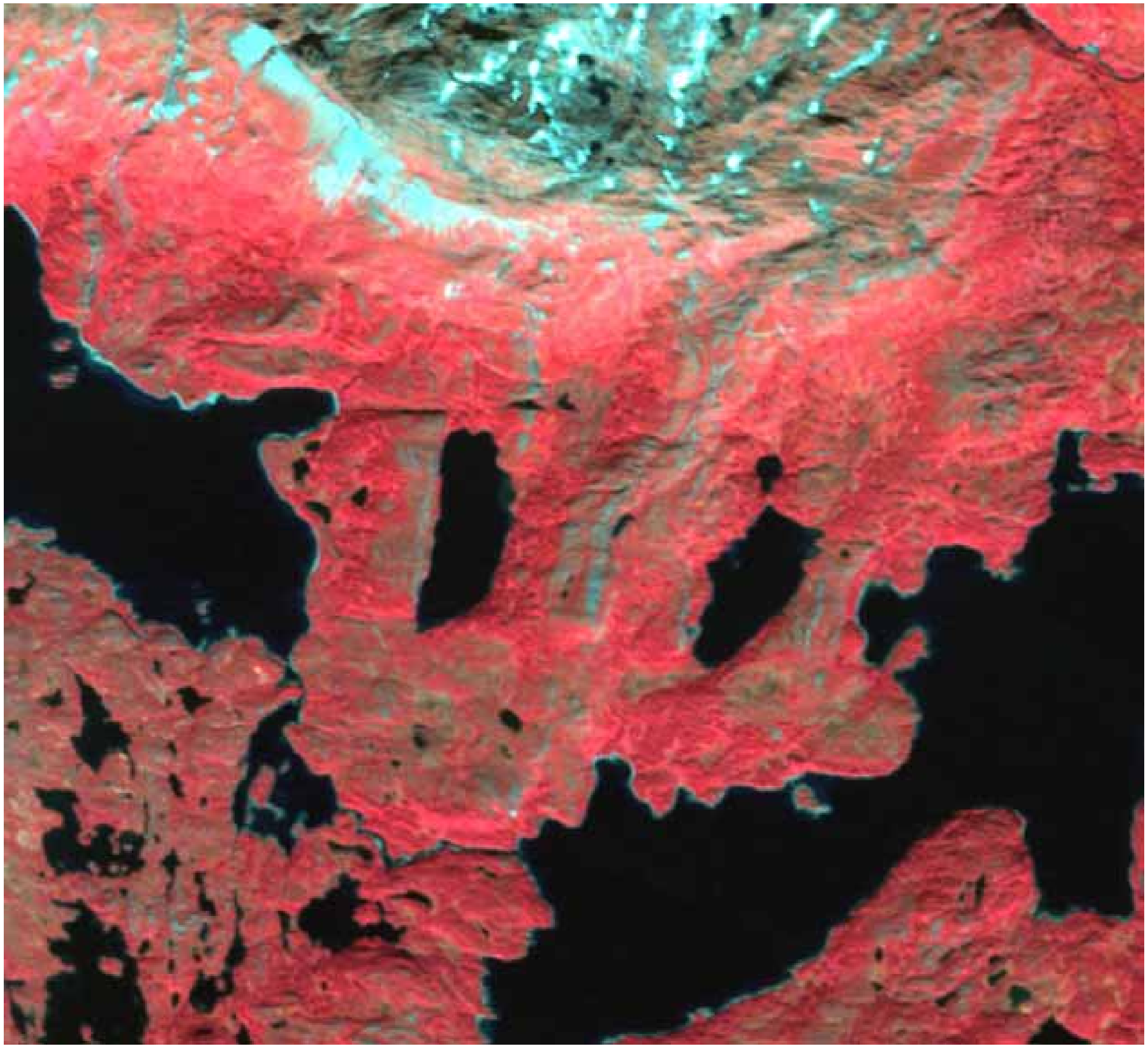
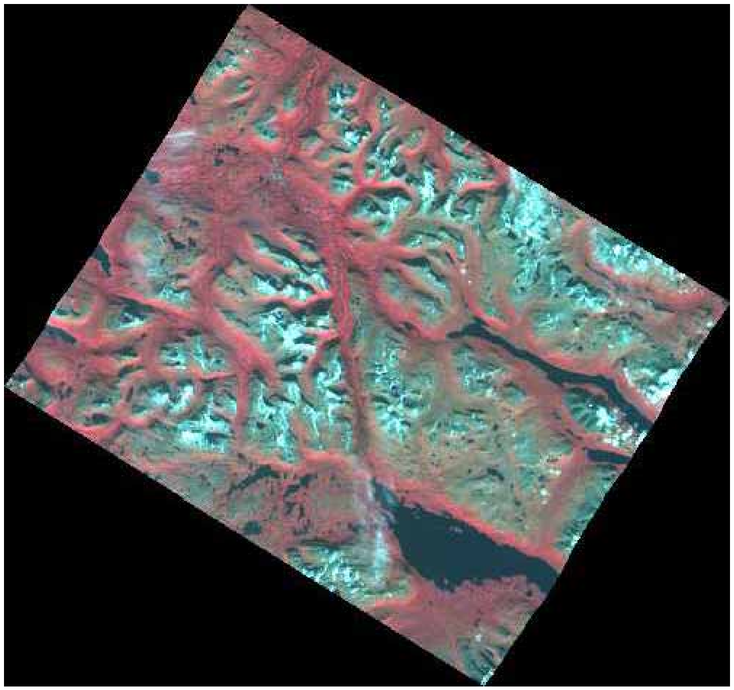
Spot data from August 24th 2008

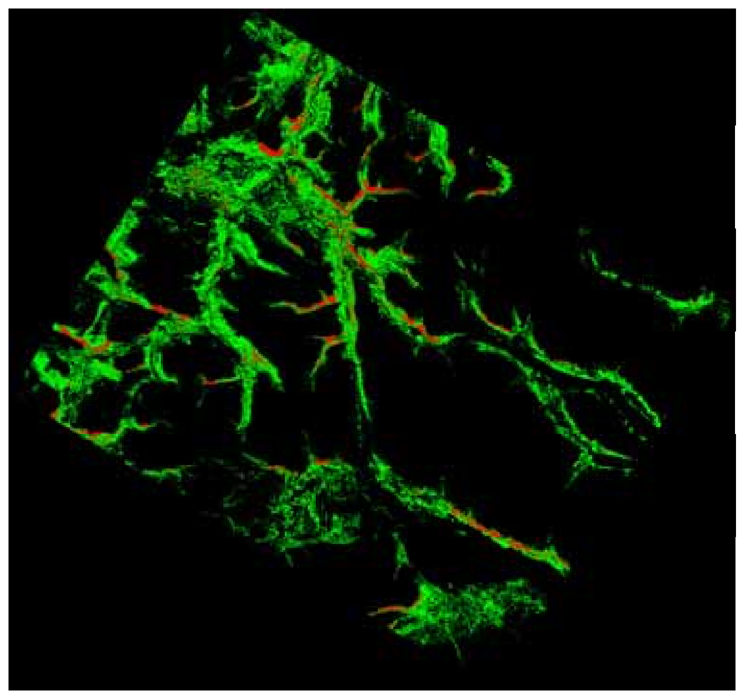


SPOT August 24th 2008
Spectral Angle Mapper classification

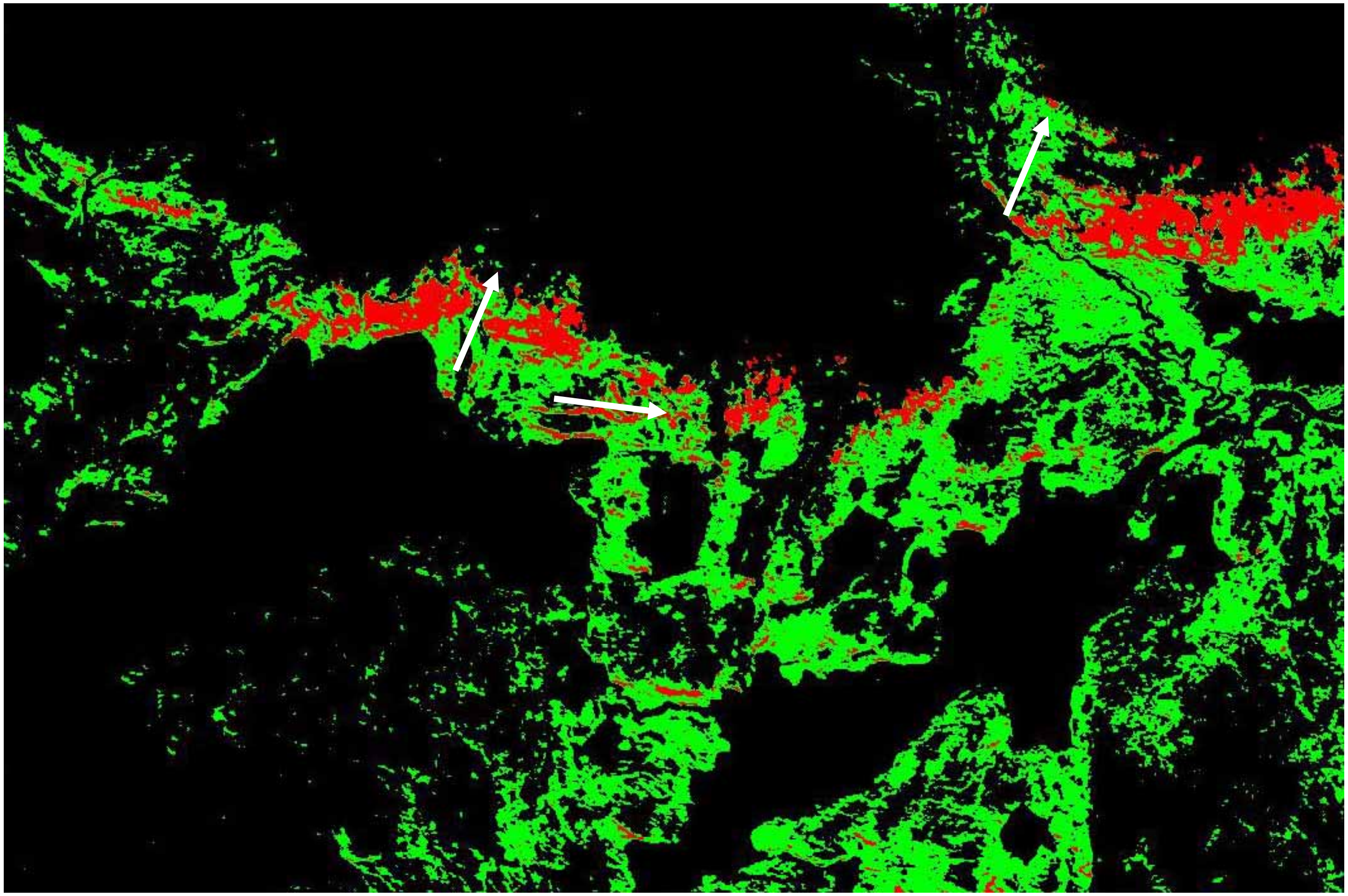


Green= birch forest

Red= Shrubs of willows and birch



SAM Njuorajavri 2008



Green= birch forest

Red=shrub of willows and birch

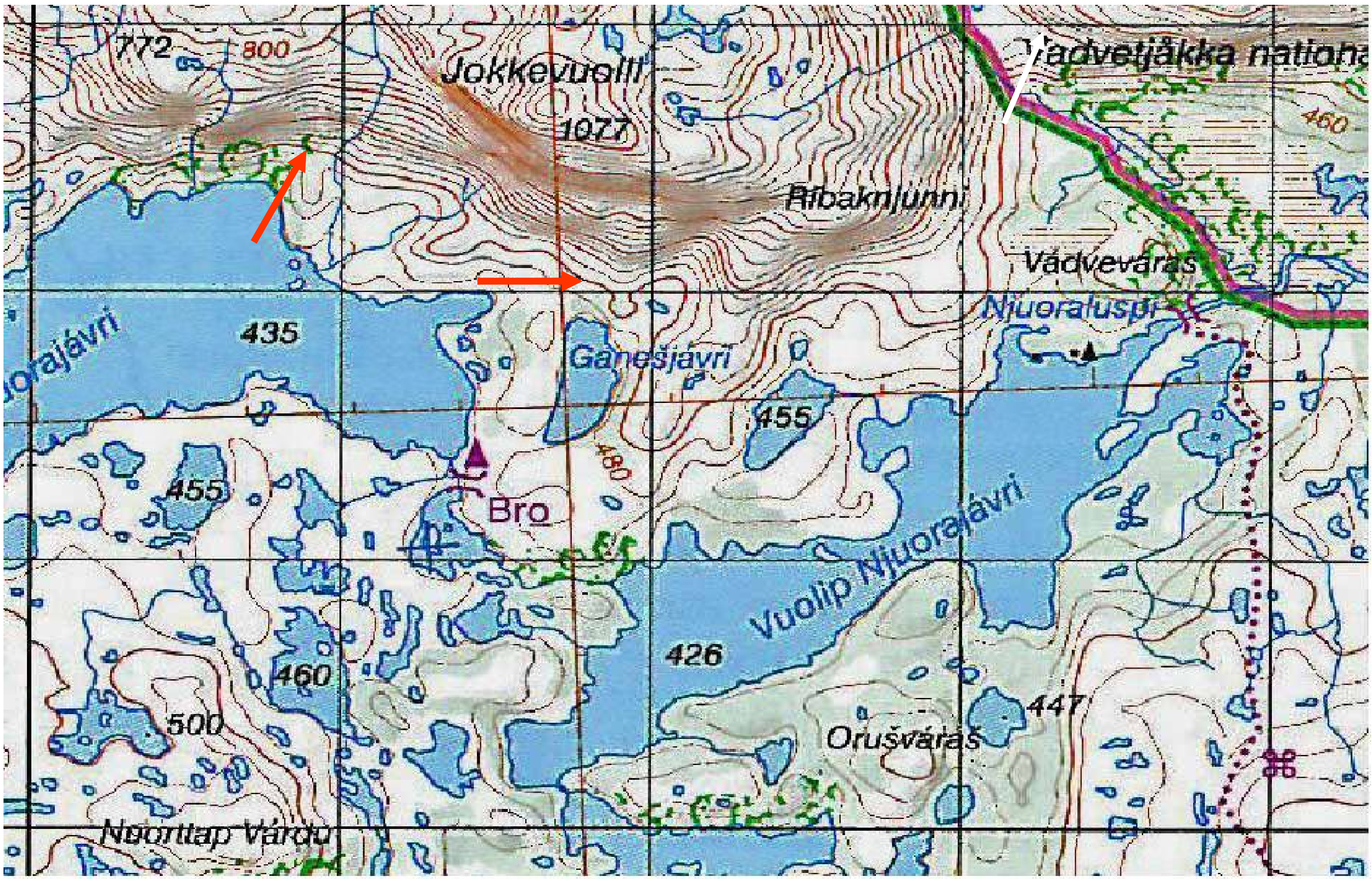
Change

1980-2008:

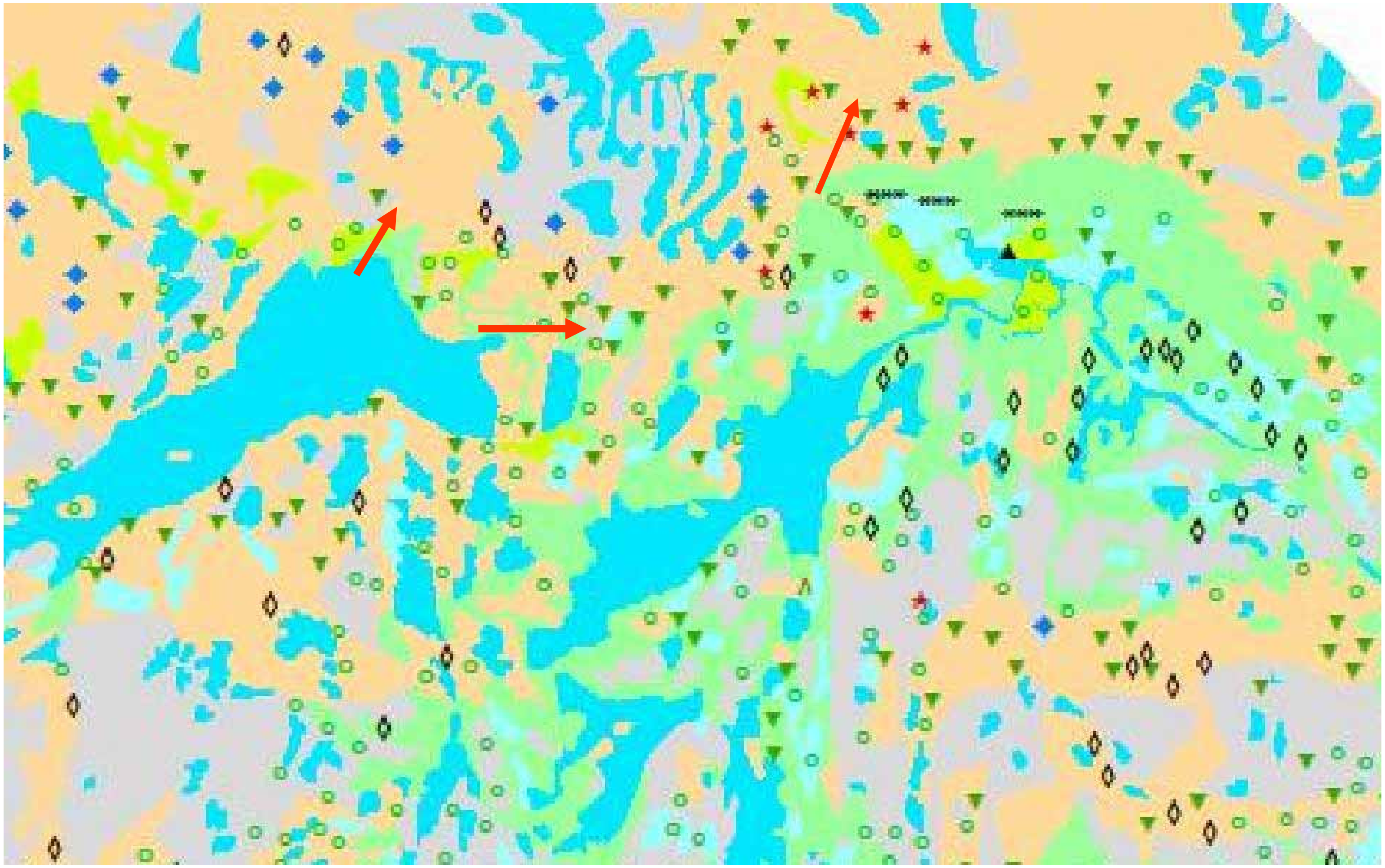
More than

20 meters

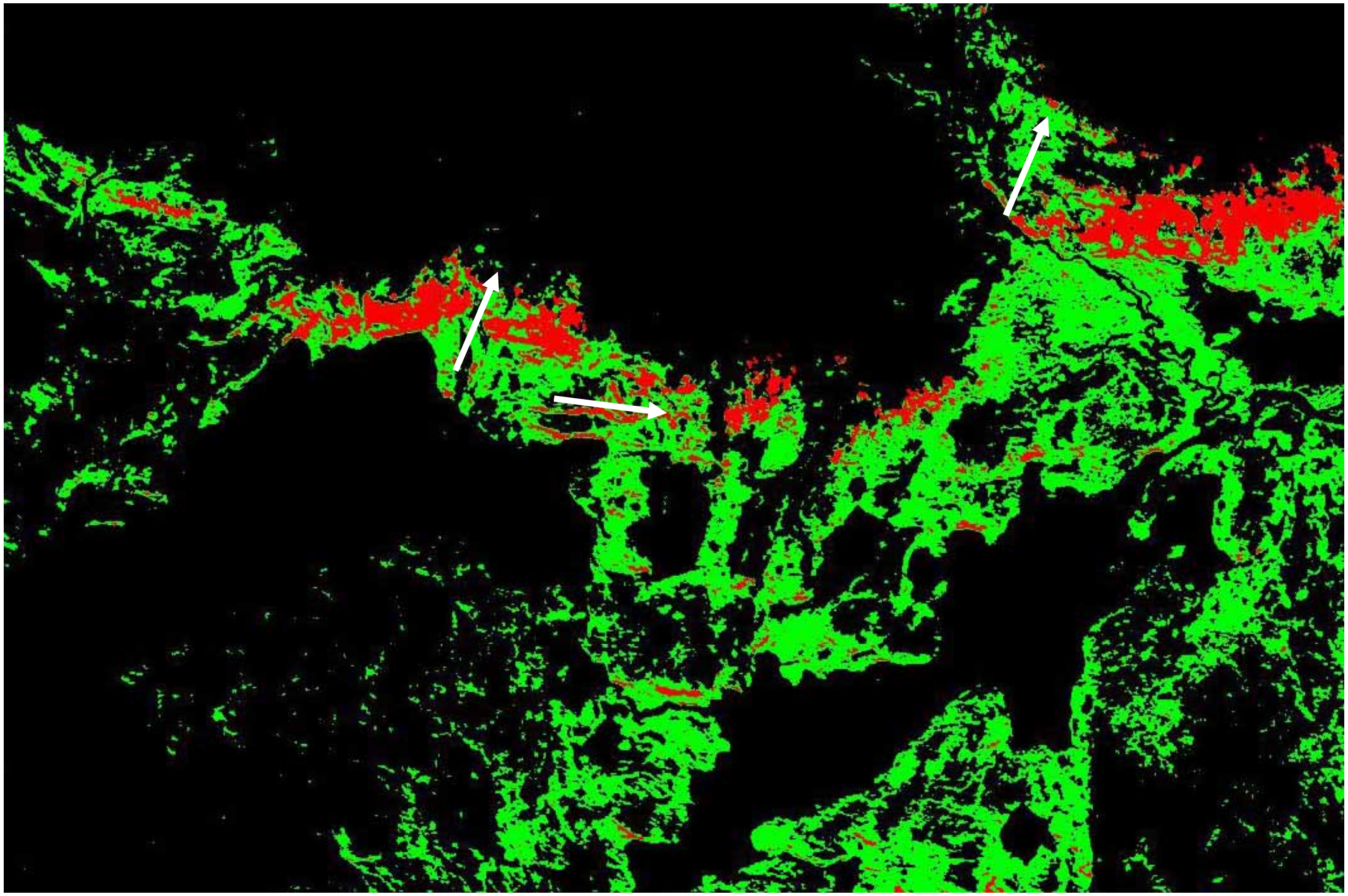
Topographic map Nuorajavri (1980)



Vegetation map 1980/82



SAM Njuorajavri 2008



Green=
birch forest

Red=shrub
of willows
and birch

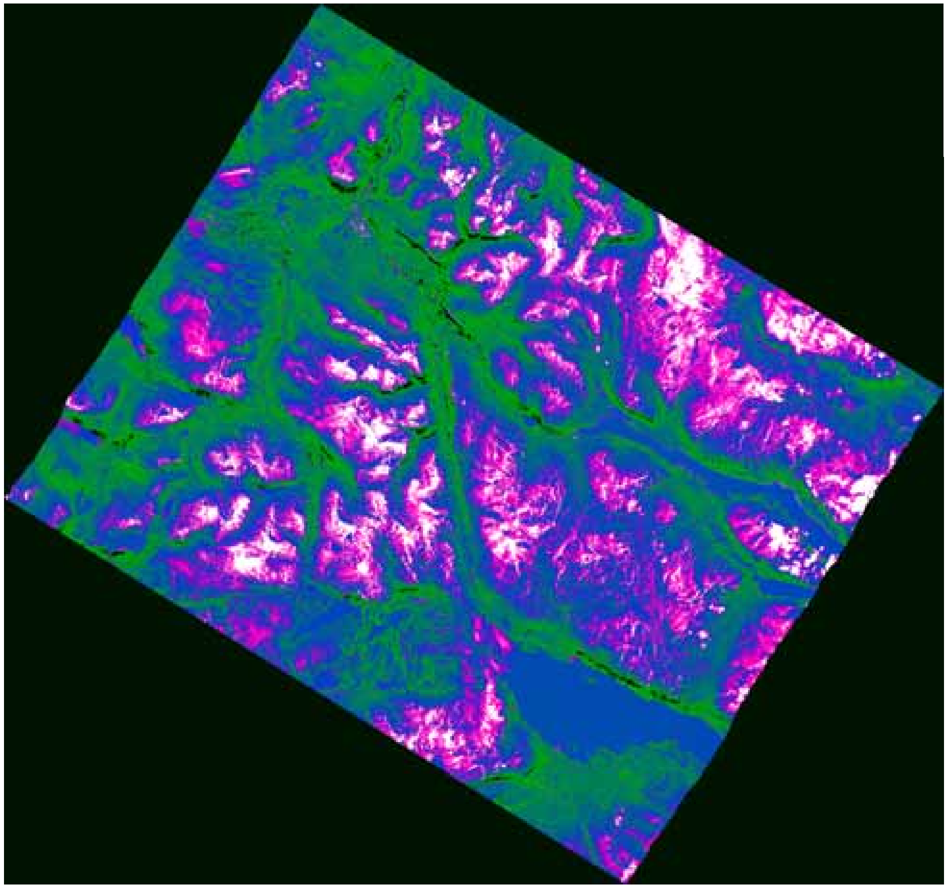
Change

1980-2008:

More than

20 meters

SPOT_UNMIXING



Birch forests in green

Results

- Change in latitude: Lakselv-Porsanger-North Cape

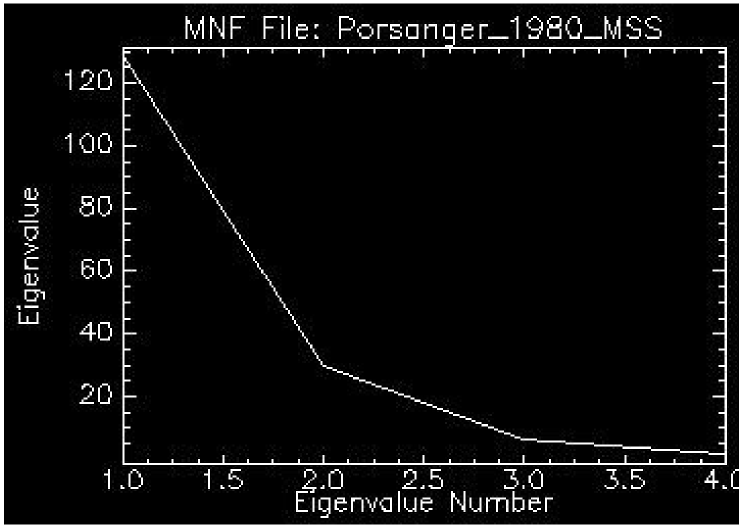
Change in latitude: Lakselv-Porsanger-North Cape

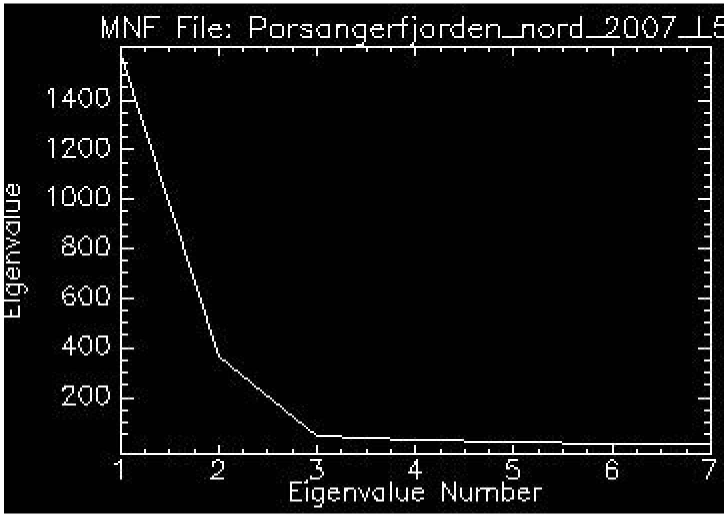
- Based on SAM-Unmixing method on:
  Landsat MSS Image from 1980 and Landsat TM image from 2007

- Compared with:
  - Topographic map 1970-ties
  - Forest cover map from about 1980
  - Forest cover map from 1914
  - Leaf area index (LAI) measurements
  - Other in situ data (tree height, etc.).

Porsanger 1980 and 2007

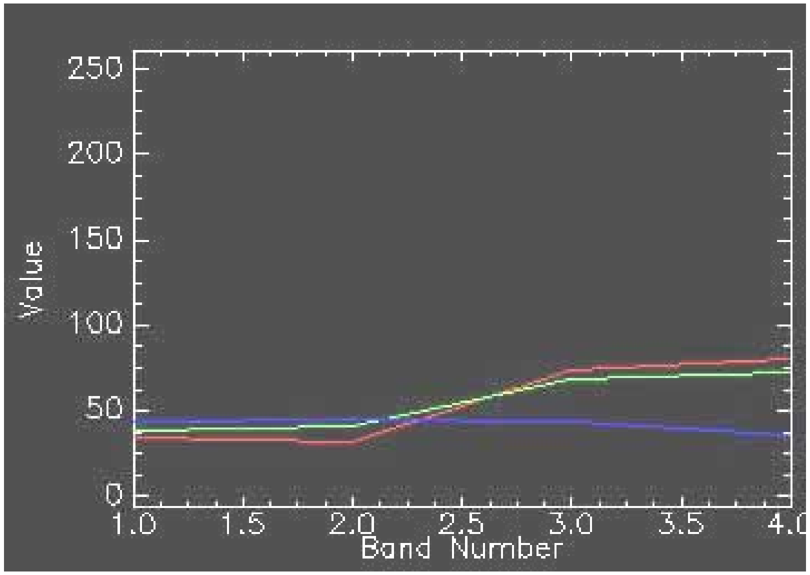
Minimum noise transform (MNF)

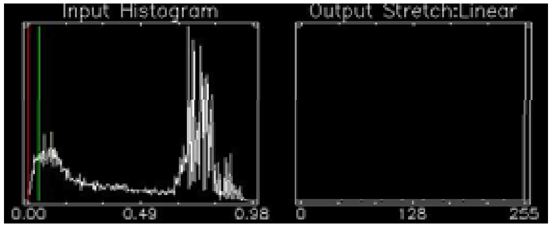


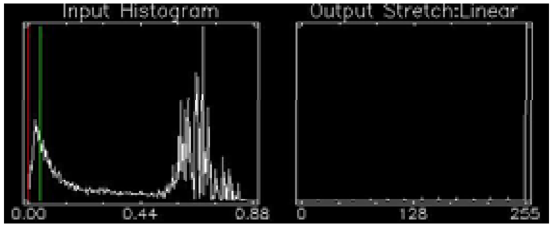


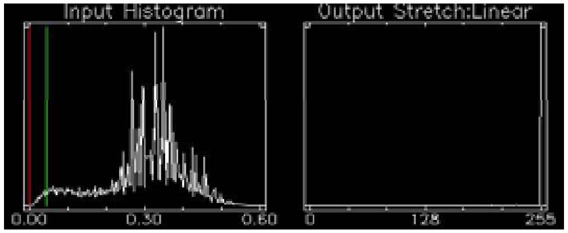
Porsanger 1980 MSS

example of spectralcurves for endmembers









Landsat MSS 1980 vs Landsat TM 2007

Green=

Birch

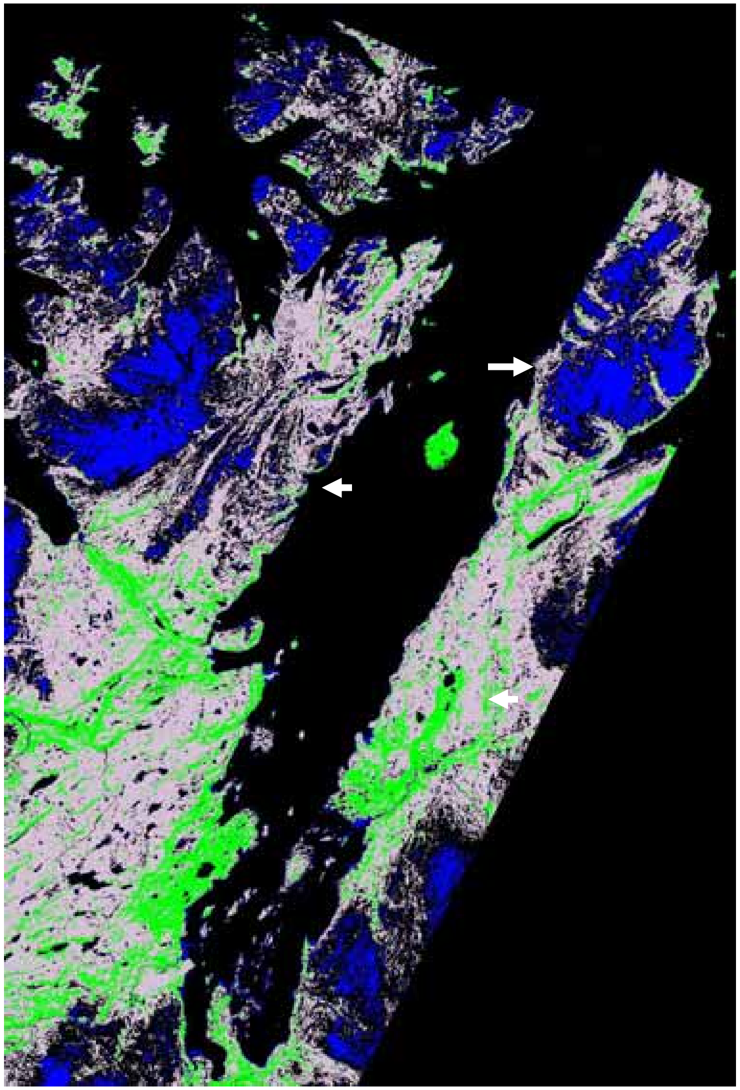
Grey=

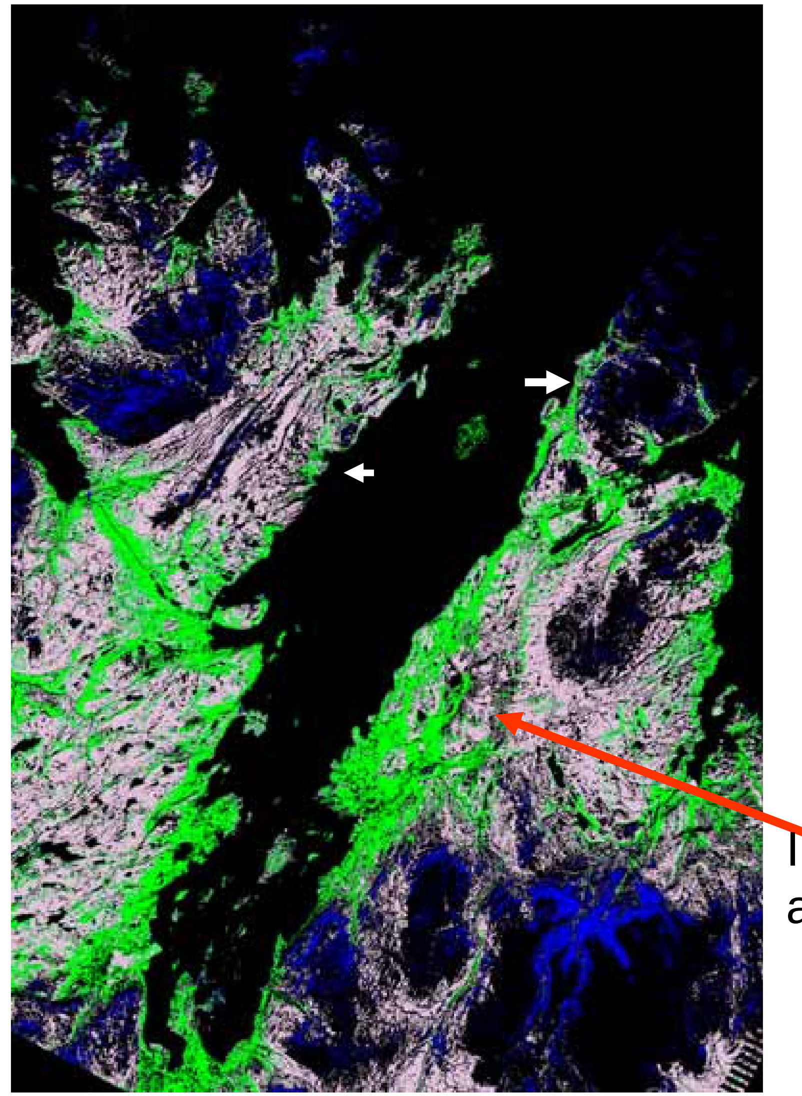
Mountain heaths/

coastal heaths

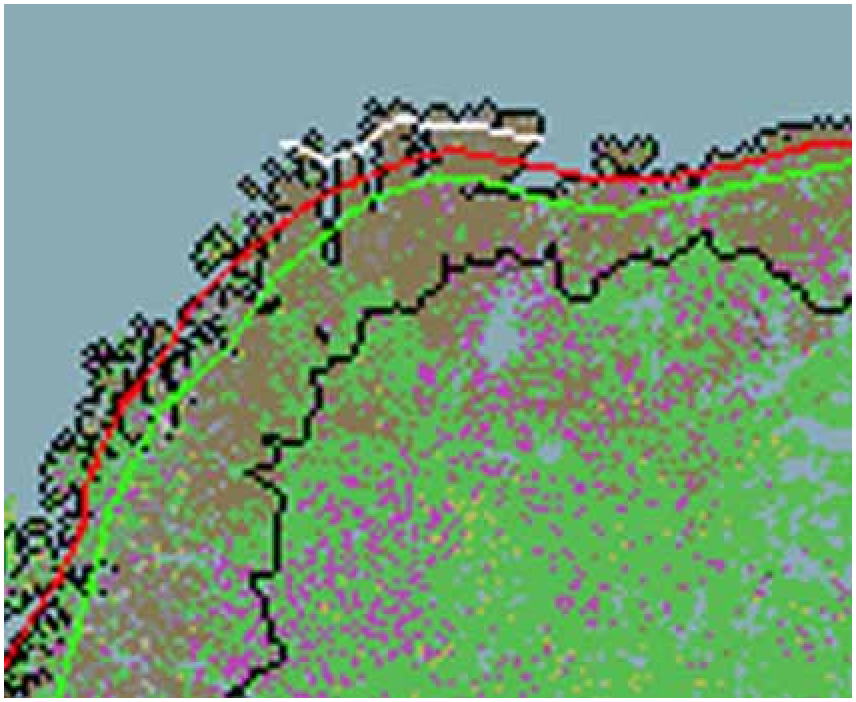
Blue=

Barrens



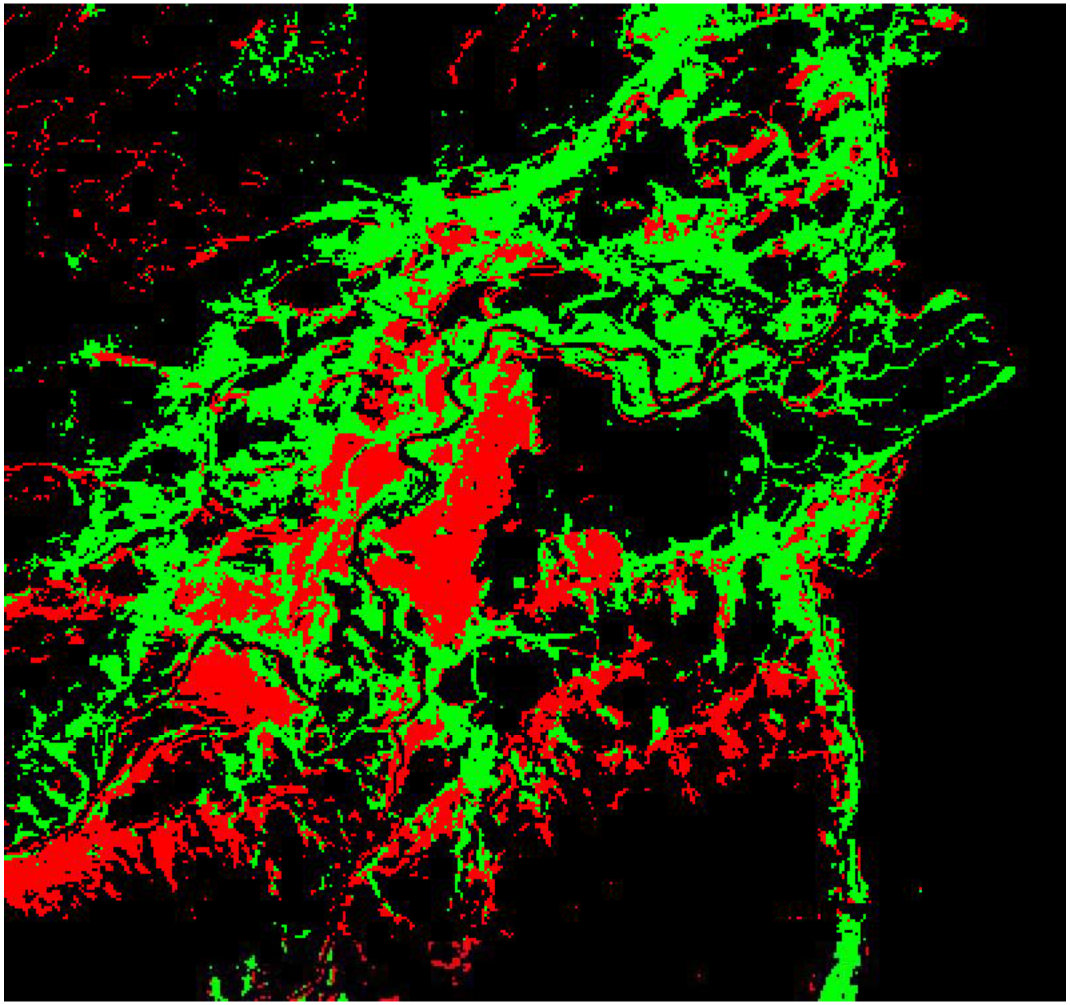


Circumpolar Arctic Vegetation Map (CAVM, 2003) to the northernmost limit of boreal forests



- Red, green and blue lines: birch, evergreen conifer and larch treelines from Hustich (1983). White line: treeline adopted by the CAVM (CAVM team 2003).

Stabbursnes; pine and birch 2007



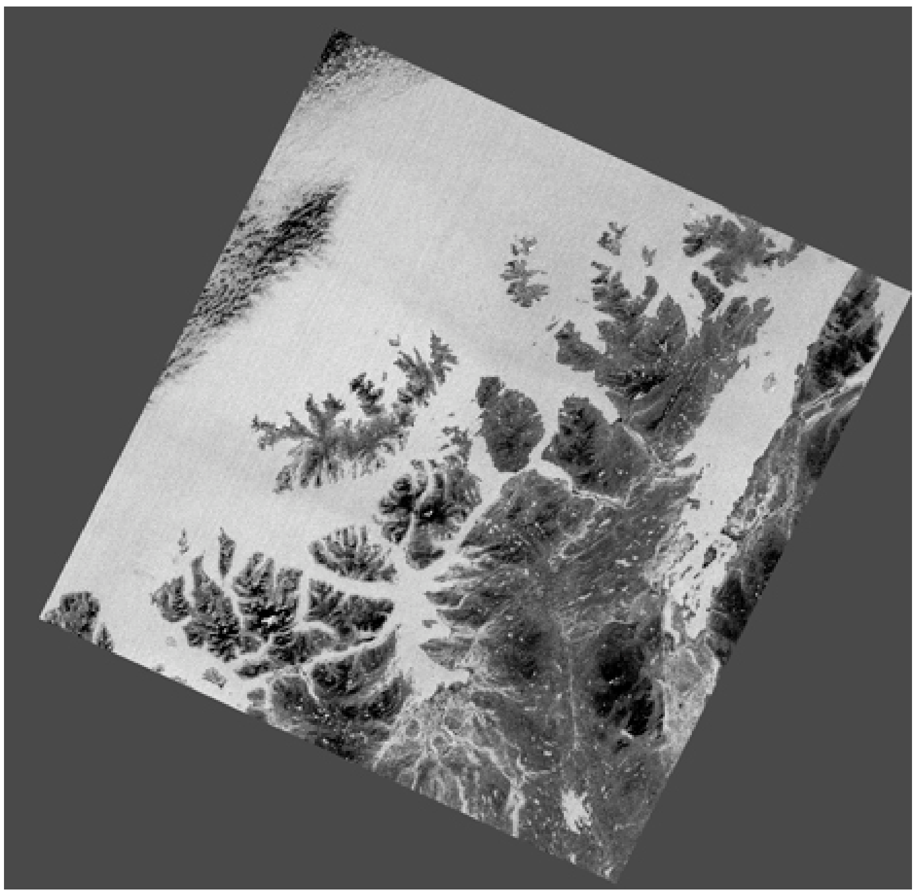
Red=Pine

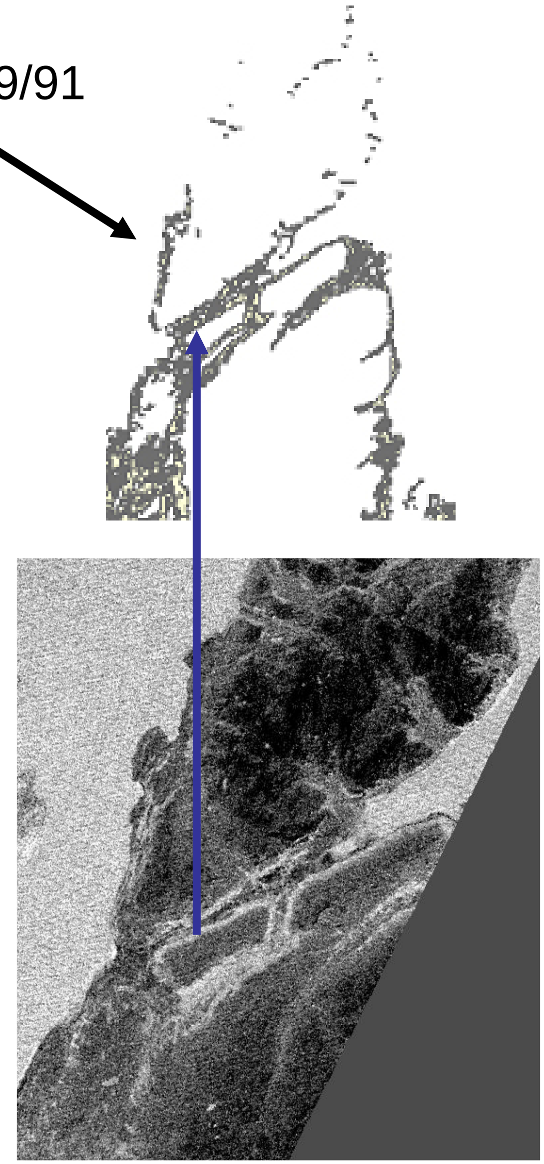
Green=Birch

UNMIXING - Birch forest 1980

Forest map 1979/91

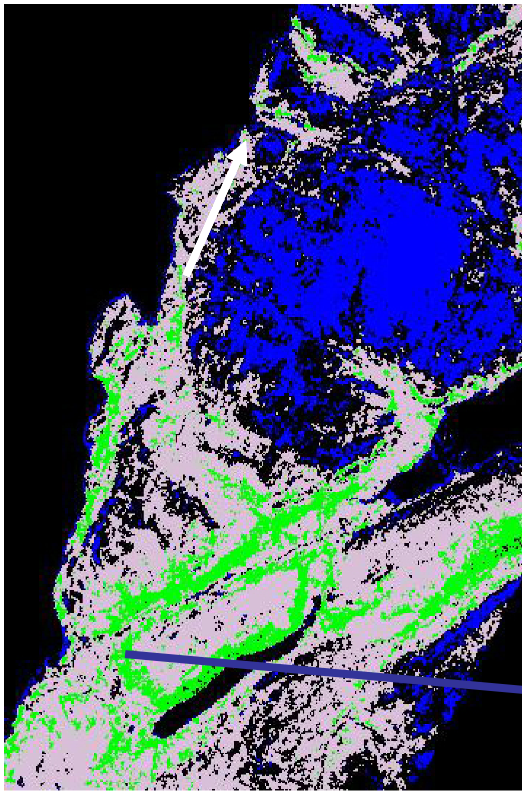
Birch forests in light grey



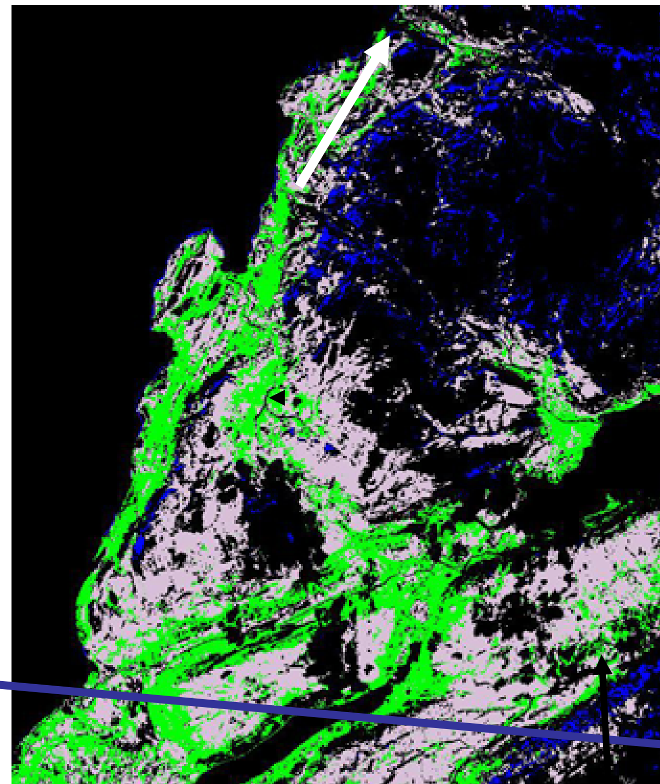


Change in forest line: 1980-2007

1980



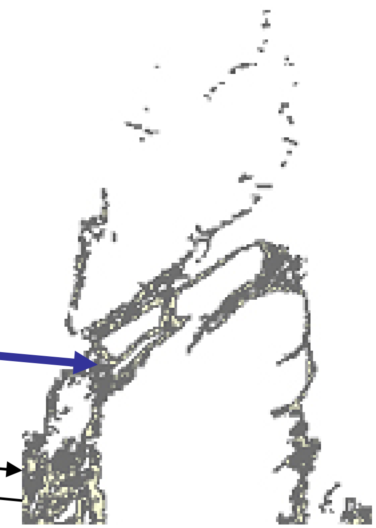
2007



Change in forestline

1980-2007:

4.1 km northwards



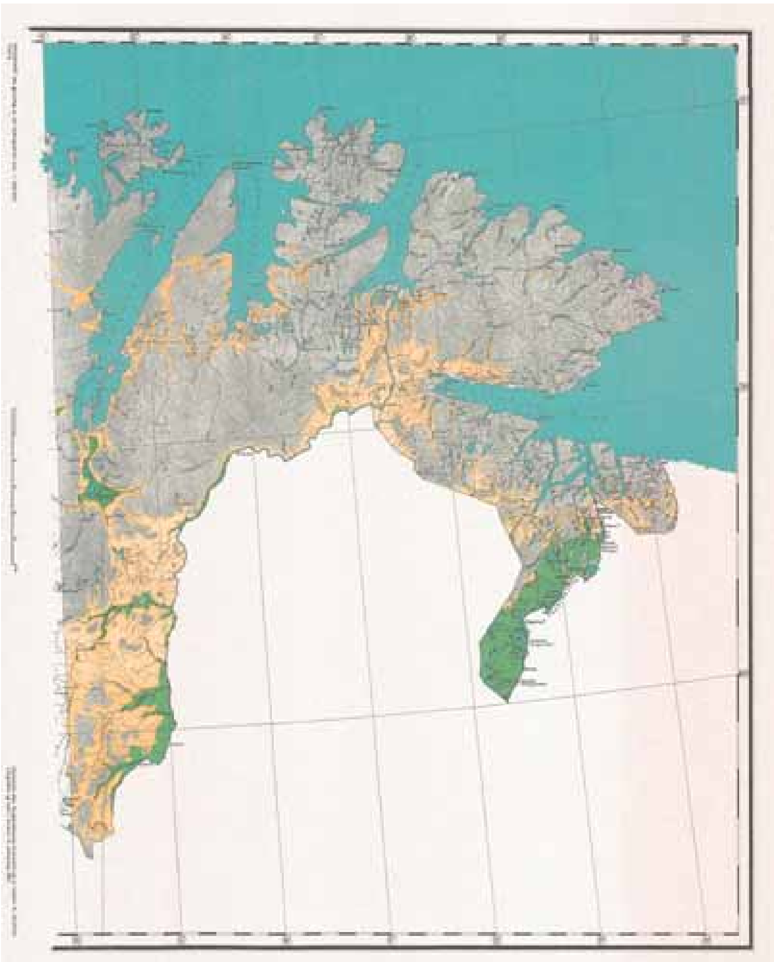
Forestline: Comparison of MSS 1980 and Forest cover map 1979/1991 =700 meters discrepancy

Forest map 1979/91

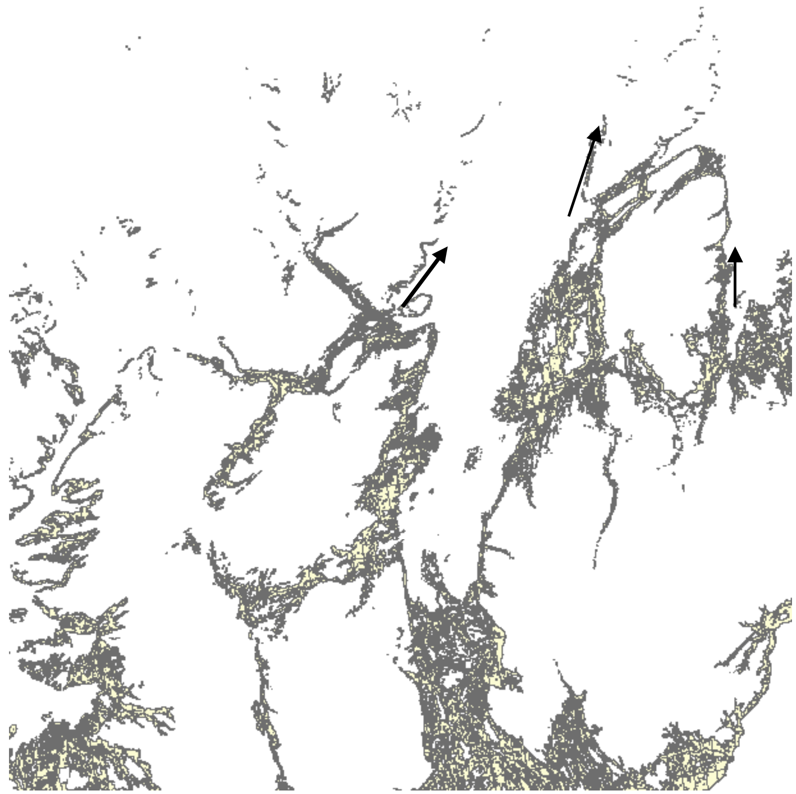
Insect-attack

Forest map from 1914 and 1979

Forest map 1914



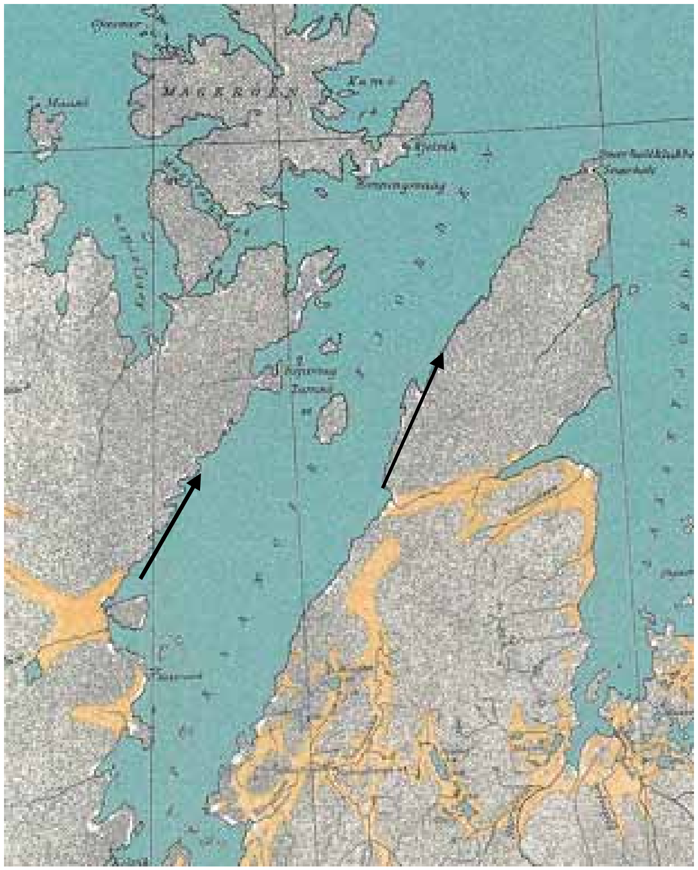
Forest map 1979/91

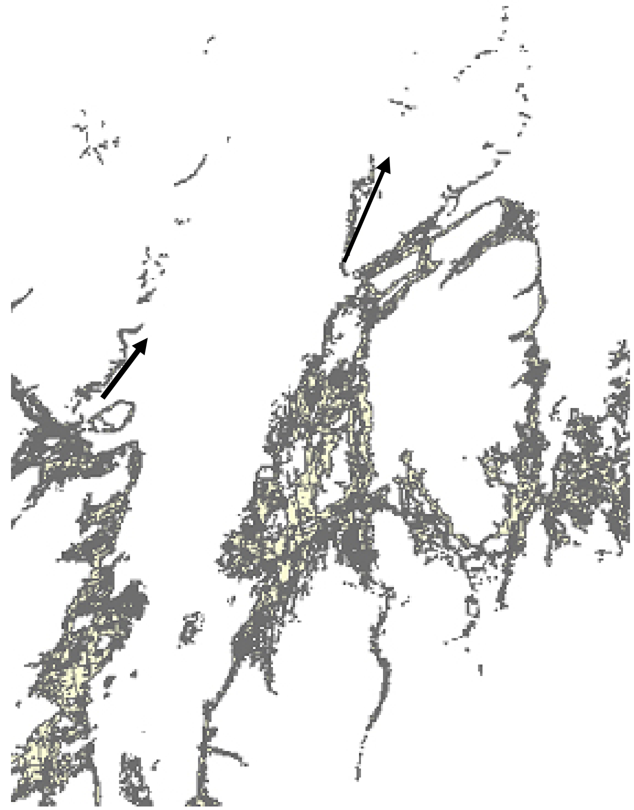


Green=Pine, Yellow=Birch

Porsangerfjord 1914 and 1979

North Cape





Change in northern forestline: 1914-1979/91: more than 30 kilometers northwards. 1914-2007: more than 34 kilometers northwards.

Preliminary conclusions I

- Altitudinal change in forest line: more than 20 meters uphill in the period 1980-2008

- Latitudinal change in forest line:

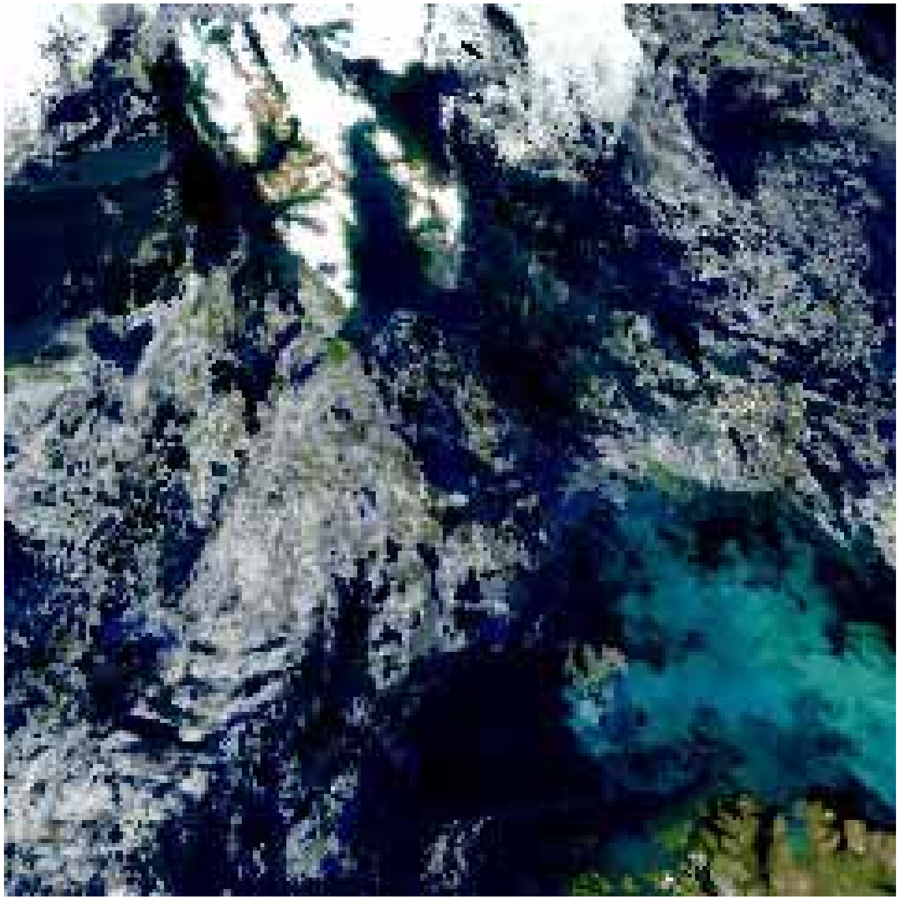
  – more than 4 kilometers northwards in the period 1980-2007

  – more than 34 kilometers northwards in the period 1914-2007

Preliminary conclusions II

- Spectral Angle Mapper (SAM) could be the best candidate for detection of the forest line since it is not so sensitive to shadows, sun elevation and illumination like the unmixing method.
- Also linear spectral unmixing will be further evaluated in order to detect the forest line.
- Insect-attacks (*Epirrita* -attacks) can harm the detection.

Further analysis on MODIS in Porsanger



Deadline: Canadian Journal of Remote Sensing June 30th 2009