

FOREST CHANGE DETECTION IN BOREAL REGIONS USING MODIS DATA TIME SERIES

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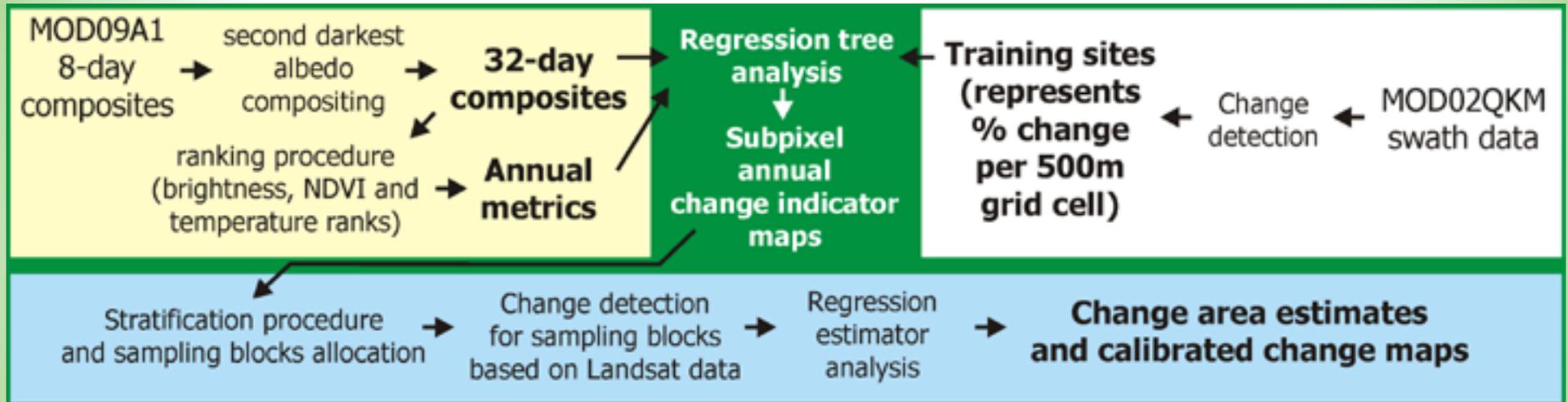


Data from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on board NASA's Terra spacecraft are imaged daily at the global scale, providing the best possibility for cloud-free observations from a polar-orbiting platform. However, MODIS data do not directly allow for change area estimations given that most change occurs at sub-MODIS pixel scales. By integrating both MODIS and Landsat data, timely forest change estimation at the global scale is enabled. This is achieved by using annual MODIS change indicator maps to stratify dominant treed biomes into low, medium and high change categories. Landsat image pairs can then be sampled within these strata, and analyzed for estimating area of forest cover loss. This poster describes the derivation of MODIS change indicator maps from 2000 to 2005 as the first step in analyzing forest dynamics in the boreal biome.

Algorithm

The analysis workflow includes two main steps:

1. Wall-to-wall change mapping using MODIS data time series.
2. Sampling and analysis of high spatial resolution images to estimate change area and calibrate MODIS change indicator maps.



Our current presentation is focused on the first stage of the project: deriving change indicator maps using MODIS data. Next stages of analysis, including sample-based Landsat data analysis and calibration of change indicator maps will be performed during the summer of 2007.

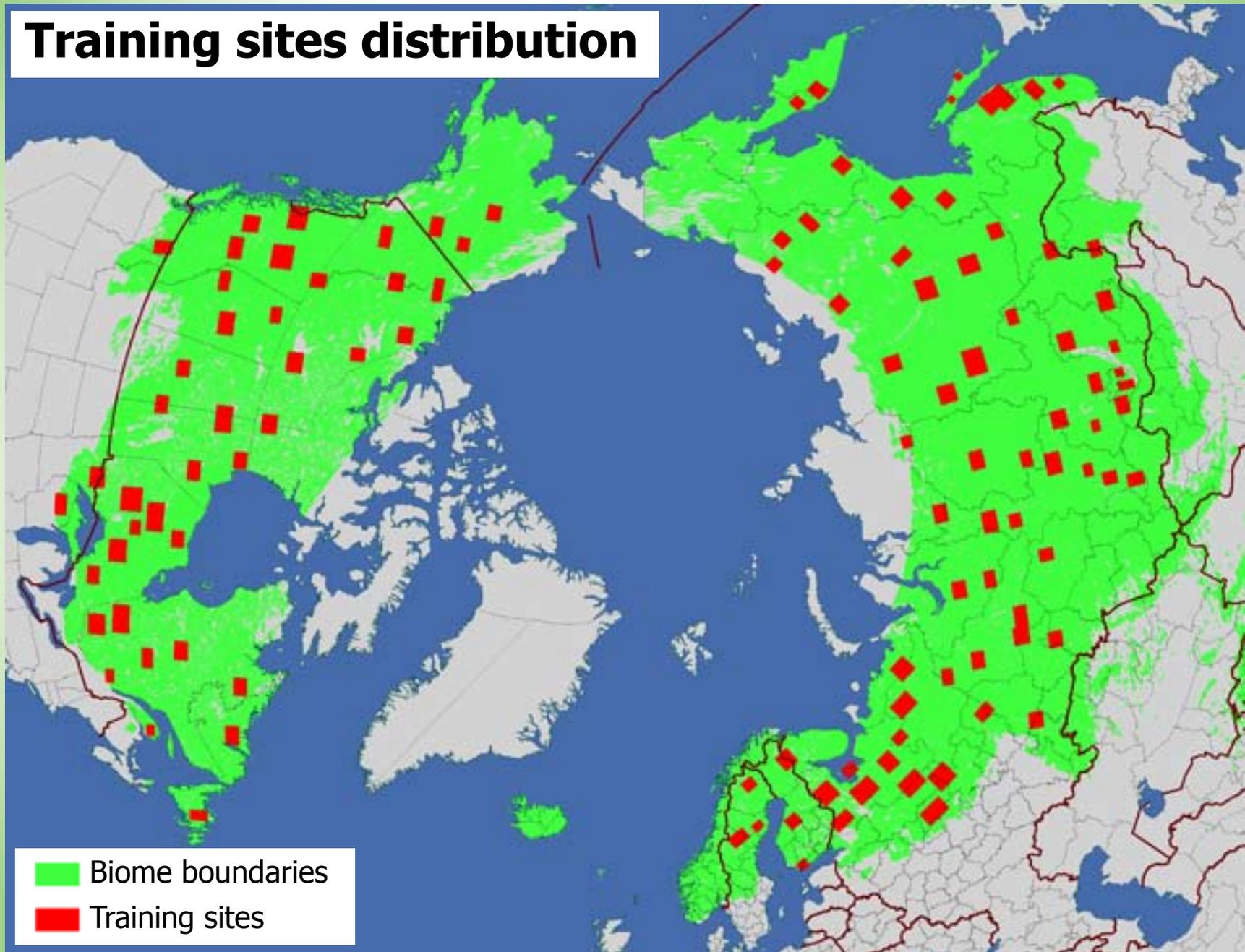
Algorithm

1. Training sites

Training sites were created on the basis of single day winter season MODIS images for February and March, years 2001 and 2005. Sites are generally equally distributed over the boreal biome and represent 5.4% of biome area. A supervised classification tree algorithm was used to map change and no change areas within sites. The final classification results (raster bitmap of change class, spatial resolution 250 m/pixel) were averaged to MODIS 500 m raster cells. In this way a continuous forest cover change training dataset was created.

Algorithm

Training sites distribution

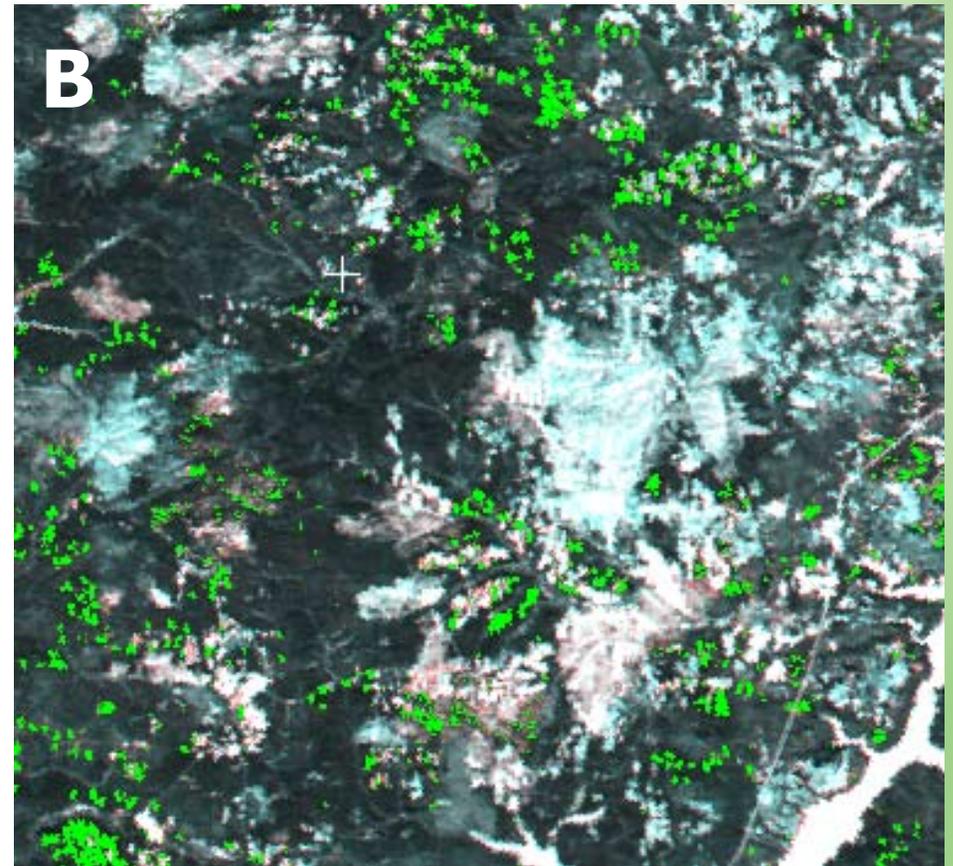
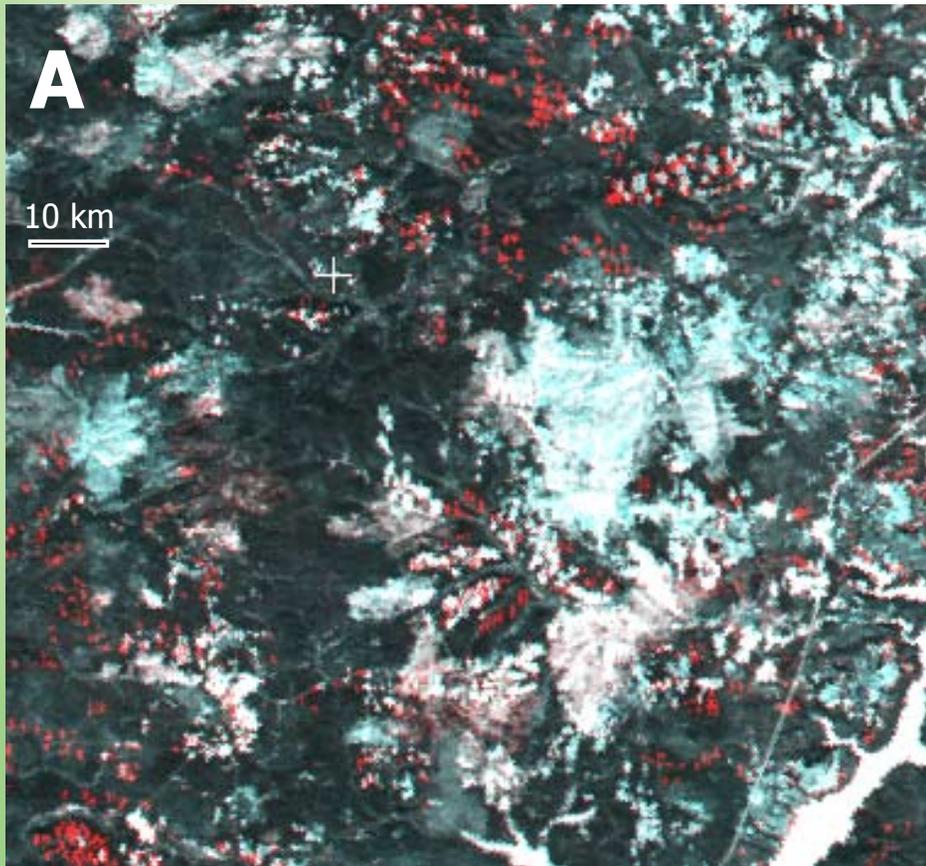


Algorithm

Example of a training site (Angara River, Russia).

A. Multi-temporal MODIS image (NIR bands) for 2001 and 2005 years. Red color reveal logging areas.

B. Change detection results (green mask) over MODIS image.

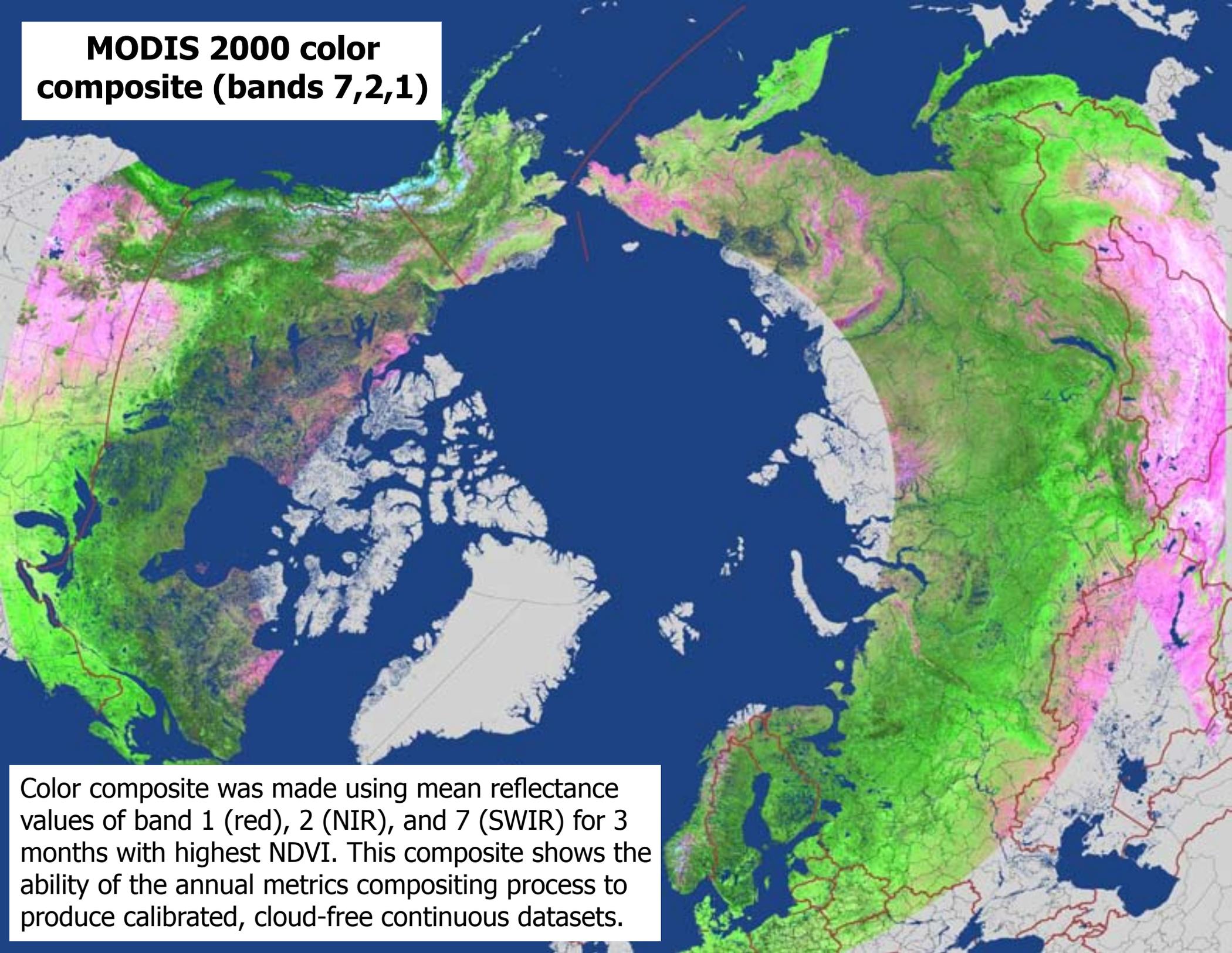


Algorithm

2. Annual metrics used for change detection

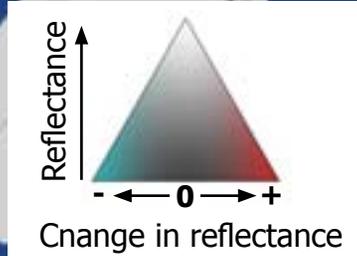
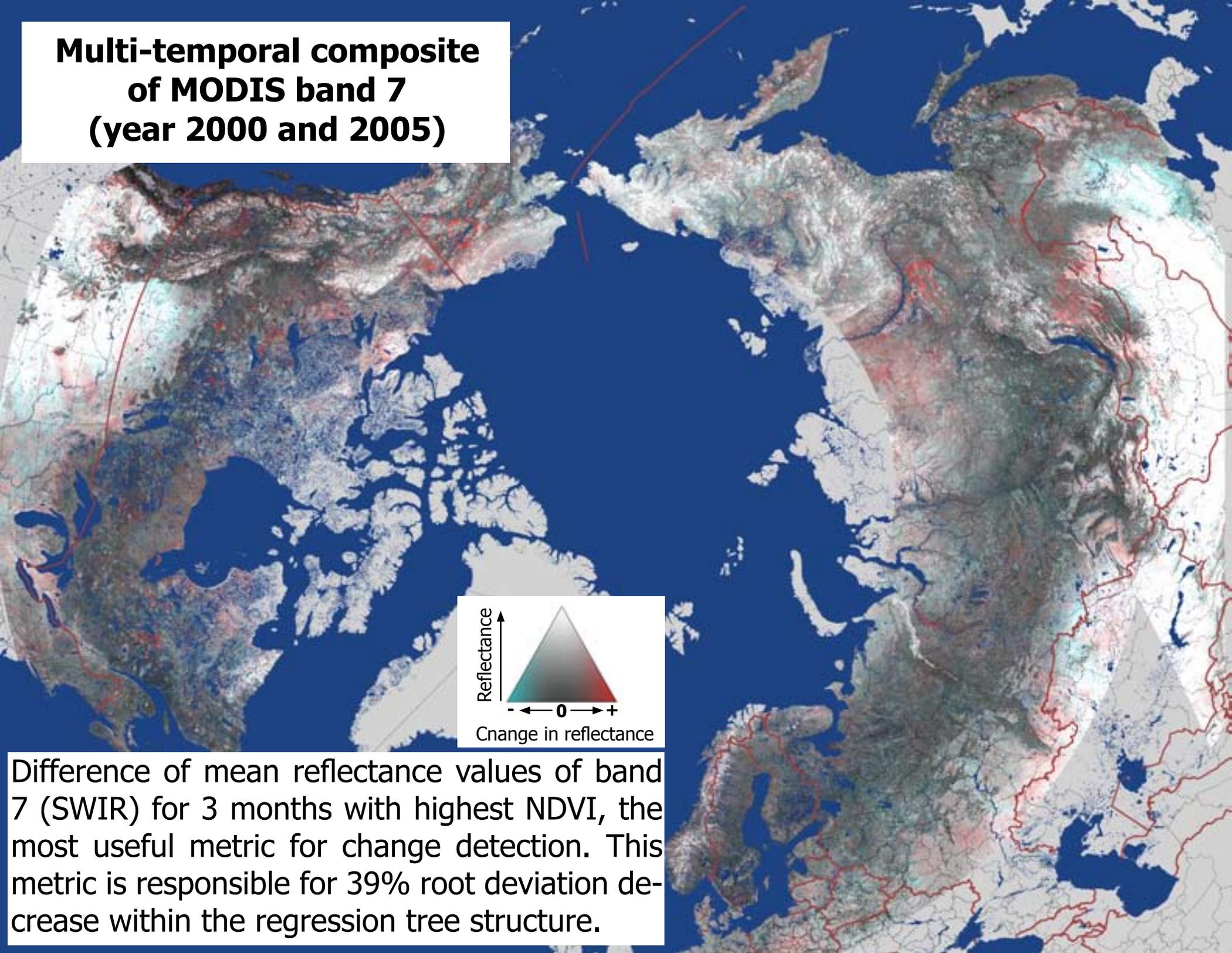
Annual multi-temporal metrics have been shown to be more useful for global medium-resolution data analysis than daily and monthly composites. The annual metrics generated from monthly composites are not sensitive to specific time of year and can limit the inclusion of atmospheric contamination. For the purposes of this study, annual sets of metrics for each year of analysis (2000-2006) were generated from monthly composites. The approach to deriving the metrics is described in *Hansen et al., Towards an operational MODIS continuous field of percent tree cover algorithm: examples using AVHRR and MODIS data, Remote Sensing of Environment, 2002.*

**MODIS 2000 color
composite (bands 7,2,1)**



Color composite was made using mean reflectance values of band 1 (red), 2 (NIR), and 7 (SWIR) for 3 months with highest NDVI. This composite shows the ability of the annual metrics compositing process to produce calibrated, cloud-free continuous datasets.

Multi-temporal composite of MODIS band 7 (year 2000 and 2005)



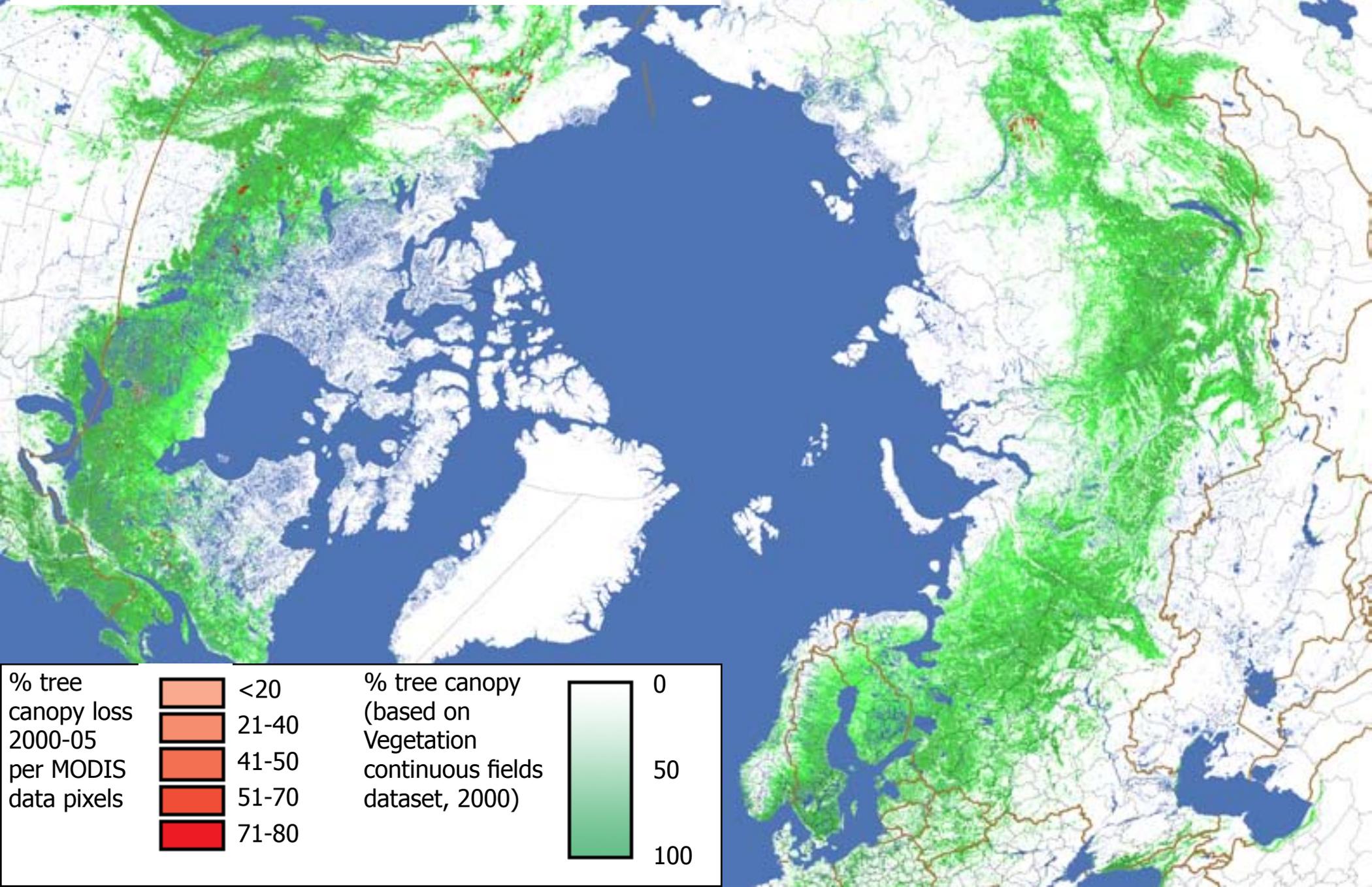
Difference of mean reflectance values of band 7 (SWIR) for 3 months with highest NDVI, the most useful metric for change detection. This metric is responsible for 39% root deviation decrease within the regression tree structure.

Algorithm

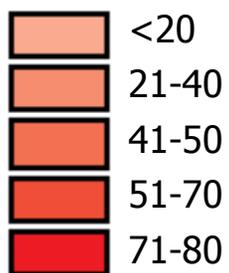
3. Change classification using regression tree

The regression tree is a nonlinear, flexible model well-suited for handling the variability present in different types of forest canopy change processes. The regression tree was used with the metrics to predict tree cover change based on the percent tree-cover change training data set. To better generalize the results over biome area and to avoid overfitting of the regression tree model, a bagging approach was undertaken. 30 samples with replacement, each representing 5% of the population, were used to create 30 regression trees. Each regression tree model was applied to the biome-wide MODIS metrics, and a median result per pixel derived.

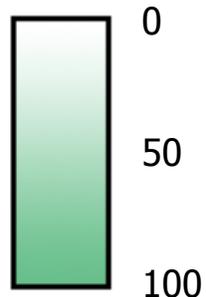
MODIS-derived forest canopy change indicator map (cumulative change for 2000-2005)



% tree
canopy loss
2000-05
per MODIS
data pixels



% tree canopy
(based on
Vegetation
continuous fields
dataset, 2000)



Results

1. Uncertainty estimation

Initial results indicate a robust method for identifying hotspots of change within the boreal region. Comparison of classification results with the whole set of training pixels shows high classification accuracy for identification of change areas: User's accuracy of 61% and Producer's accuracy of 63% (using 5% change threshold for results to clean noise). Mean error for subpixel change estimation in comparison with training is 0.63 with standard deviation of 7.44. However, the classification results show an underestimation of change area, especially in the high change stratum, which drives our total area of change estimation. To compensate for this underestimation, we apply a scale factor (1.5) to all our change estimates.

Results

2. Spatial distribution of forest change areas

The extent of the boreal biome used for the change analysis is 2530 million ha. Our analysis was focused on forested lands (except Iceland) with an area of 1239 million ha (calculated on the base of the VCF product). Total change area (calculated as the sum of sub-pixel change values) for the period 2000-2005 is 9.7 million ha which represents 0.78% of the biome's forest area. Using the scale factor derived from the comparison of results with training data modified the change estimation to 14.8 million ha which represents 1.19% of biome's forest area. Both estimations should be considered as preliminary and will be calibrated on the basis of the high-resolution data analysis.

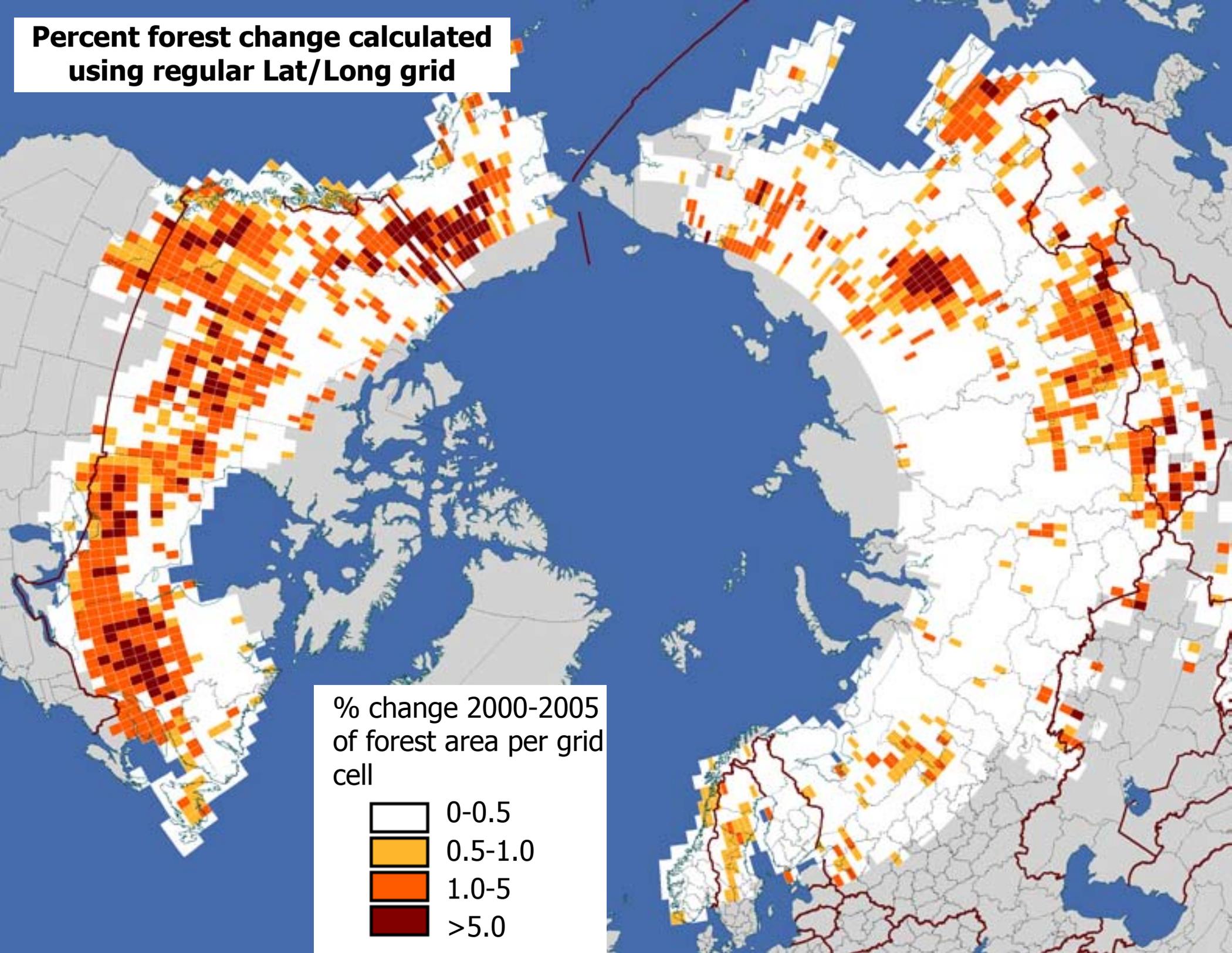
Change areas are distributed unevenly within the biome. The largest change areas are connected with regions of intensive logging operations (southern parts of Ontario, Québec and British Columbia) and of large scale wildfires (Northern Canada and Alaska, Central Siberia and Far East).

Results

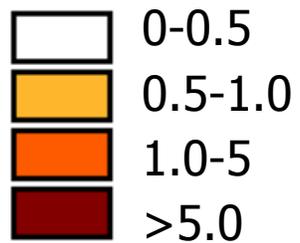
Distribution of boreal forest change area for years 2000-2005 per country

Country	% change of forest area	% of total biome change
Canada	2.1	56.8
China	0.6	1.0
Finland	0.1	0.2
Kazakhstan	0.3	0.1
Mongolia	0.8	0.3
Norway	0.2	0.1
Russia	0.6	25.8
Sweden	0.5	0.8
USA	3.1	15.0

**Percent forest change calculated
using regular Lat/Long grid**



% change 2000-2005
of forest area per grid
cell

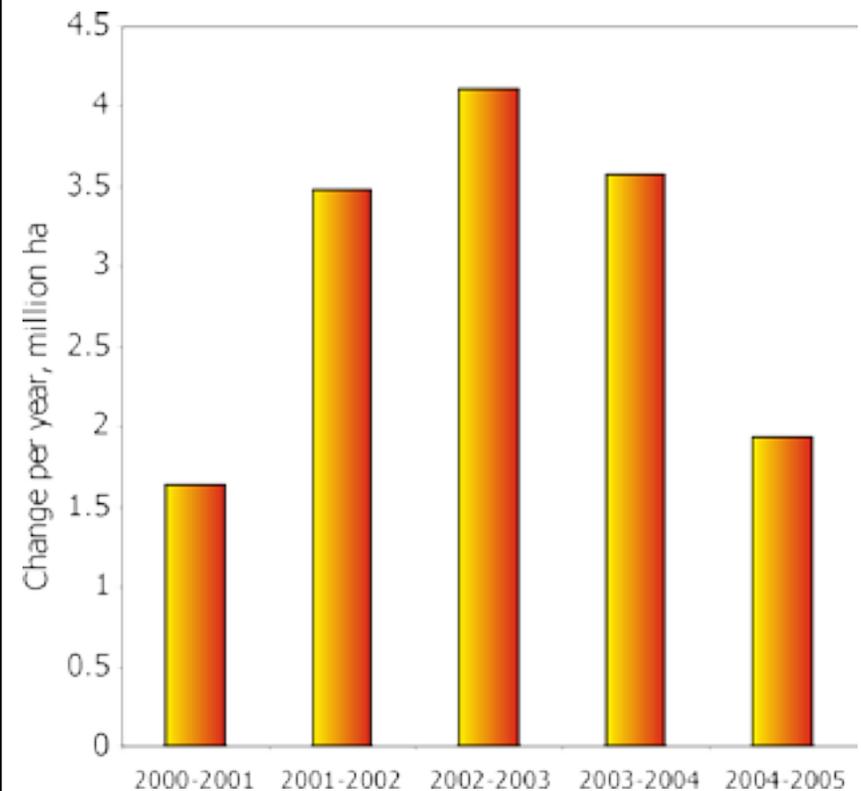


Results

3. Temporal distribution of forest change

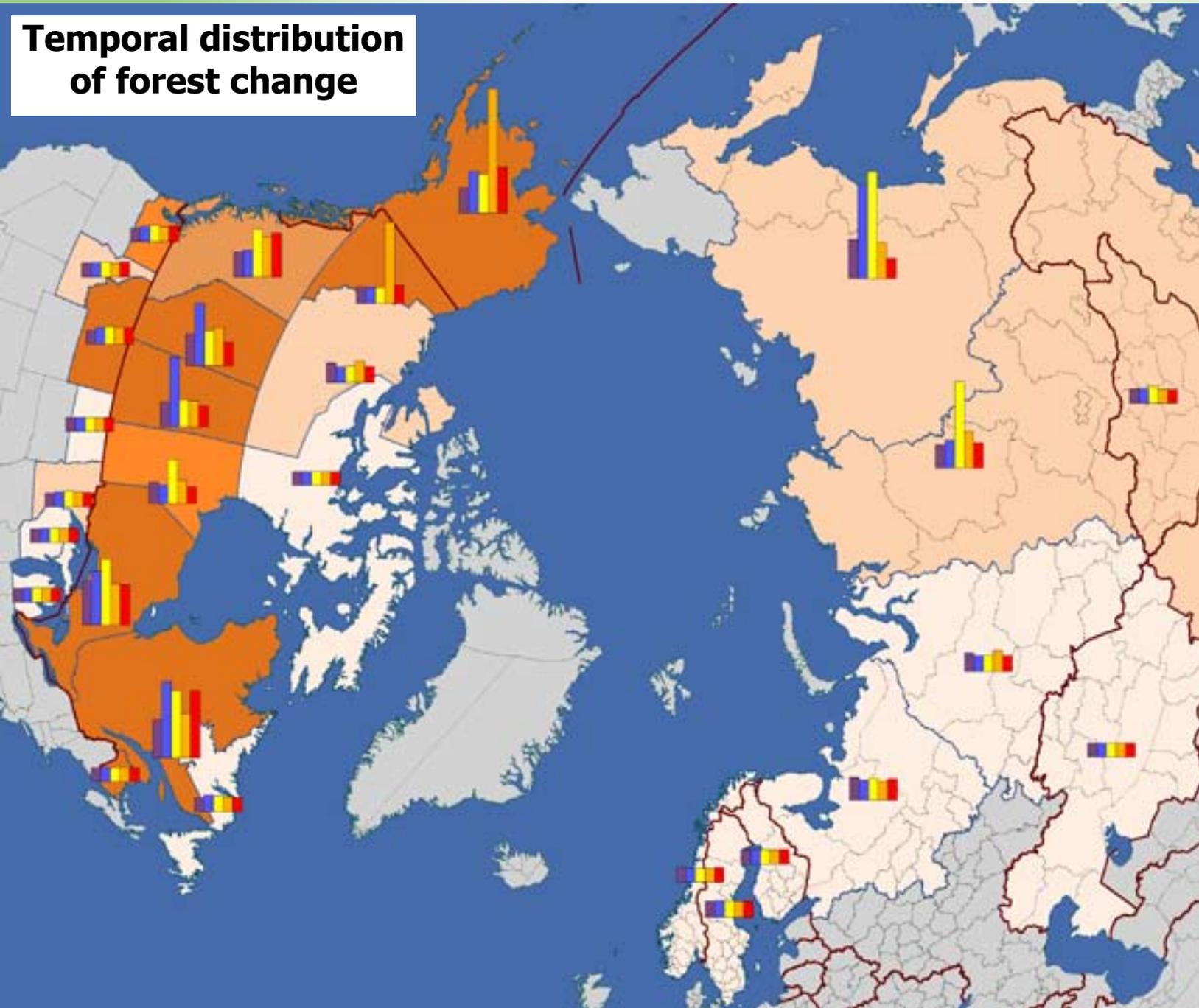
Analysis of change area distribution using annual intervals highlights years with high wildfire activity. Our results show interannual differences in fire activity for regions in North America and Eurasia. For example, the increase of total change area in 2002 was connected with fires in Central Canada and Yakutia, in 2003 with fires in Siberia, in 2004-2005 with Alaskan fires.

Distribution of total forest change area per year for boreal biome



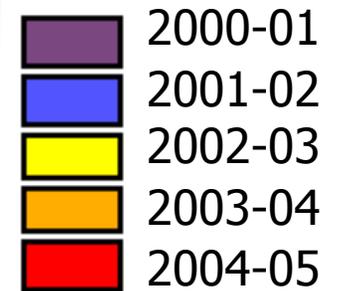
Results

Temporal distribution of forest change

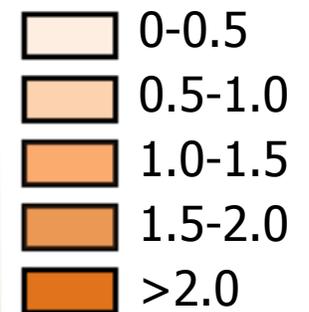


Forest change area per year for selected regions

■ 100 th. ha



Percent forest area change 2000-2005 per region



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