Russian Academy of Sciences
Space Research Institute (IKI)

Russian Forests Status and Dynamics in 21st Century as assessed with Earth Observations

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Lesson at 15th All-Russia open School-Conference on Fundamental Issues in Earth Observations

Space Research Institute (IKI), Moscow, November 11, 2019

How well we know Russian forest

- Forest area is ~ $815x10^6$ ha or ~ 20% of global forest coverage - World largest forest (FAO, 2016)
- However information about Russian forest is critically out-dated. Some remote regions of Siberia and Far East never been properly inventoried, only 15% of entire forest area of country has been inventoried less than 10 years ago
- Wildfires, insects out-breaks, diseases, windstorms, droughts and some others are among main natural factors for forest disturbances, but most of them (excluding fires) are not well quantified and are not of subject for regular monitoring

Russian Forests & Climate Change

– The concentration of GHG's in the Earth atmosphere is widely considered as main driving factor for global climate change

– Most rapid air temperature rise is observed in the boreal region, particularly in Russia. The country is warming 2.5 times faster than the rest of the planet

– Russia has adopted Paris climate agreement on Sept 23, 2019 and "proceeds from importance of keeping and **increasing the absorbing capacity of forests and other ecosystems and the need to maximize its consideration**, including when implementing mechanisms"

Carbon Budget in Russian Forests

- The existing estimates of the carbon budget in Russian Forests are highly uncertain (3-4 times difference). The source of uncertainty is, first of all, the lack of reliable and relevant information on forests status and dynamics
- With the adoption of the Paris climate agreement the importance of reliable information on Russian forests is significantly increased
- Today the Earth Observations is only realistic method to fill the gap of information about Russian forests for accurate carbon budget assessment

RS data derived essential forest variables for Carbon Budget Assessment

- Forest and non-forest land cover types
- Dominant tree species and their composition
- Forest growing stock
- Forest density (relative growing stock, cover fraction)
- Forest Age
- Forest Site Index
- Forest biophysical characteristics (LAI, FAPAR)
- Forest disturbances, including:
  - burnt area and severity
  - other natural and human-induced disturbances
  - logging

Main component of R&D at IKI

(I) Multi-annual of automatic near-real-time update EO data archive

(II) Automated EO data processing chains, including:

a. EO data pre-processing (cloud/shadow screening, image compositing, vegetation indexes generation, data time-series reconstruction and etc)

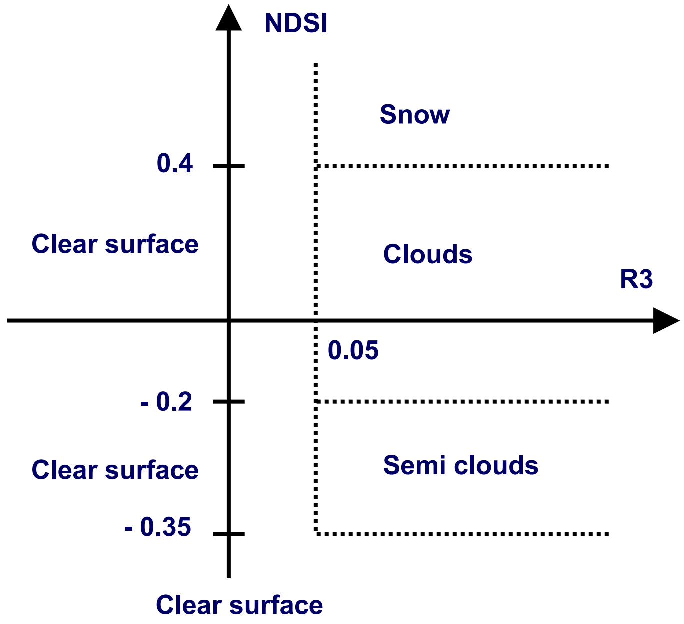
b. Thematic products generation (land cover, tree species, growing stock, active fires, burnt area and severity, etc)

(III) Web-based Users' Interface with data analysis tools

MODIS data archive at IKI

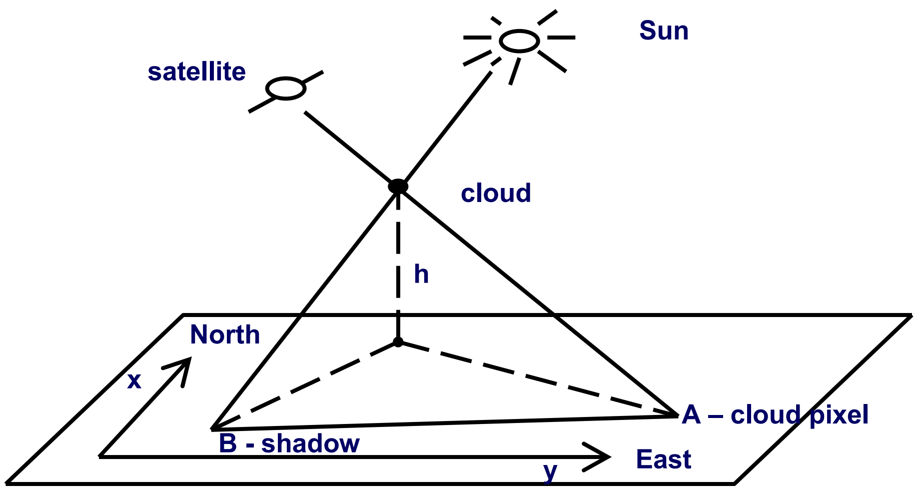
- MOD09 Surface Reflectance standard product from NASA
- Geographical coverage: Russia and neighbouring countries
- Period of time covered: 2000 – ongoing
- Daily temporal resolution
- 250 & 500 m spatial resolution
- Near-real-time update

MODIS data preprocessing

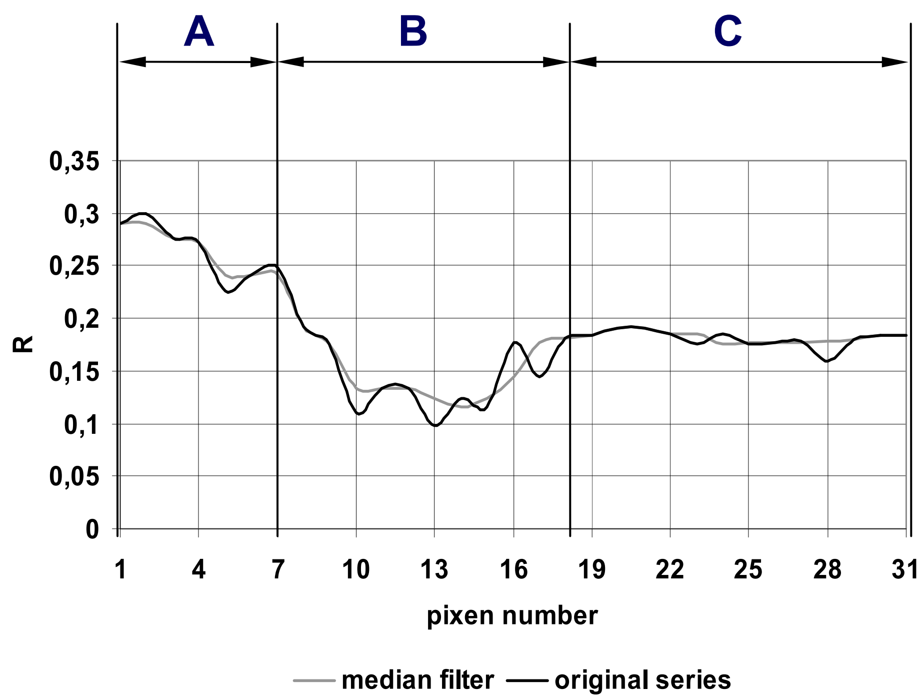


Daily data masks creation:

1) Snow and clouds detection
2) Shadows detection
3) Statistical filtering



Geometry of shadow line



Shadow line analysis

EO data preprocessing

Cloud screening

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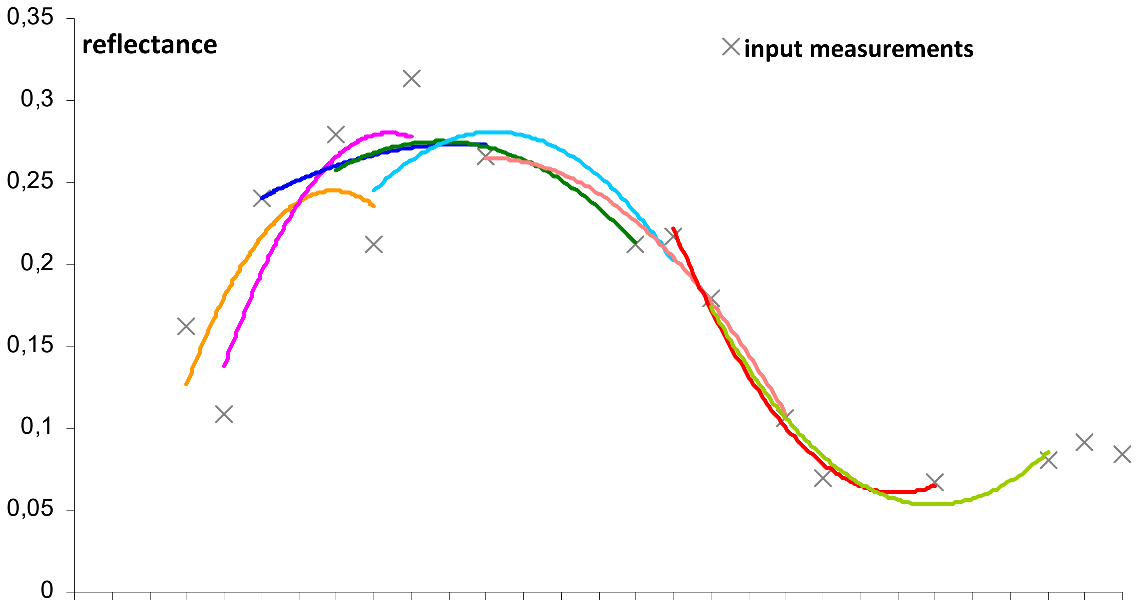
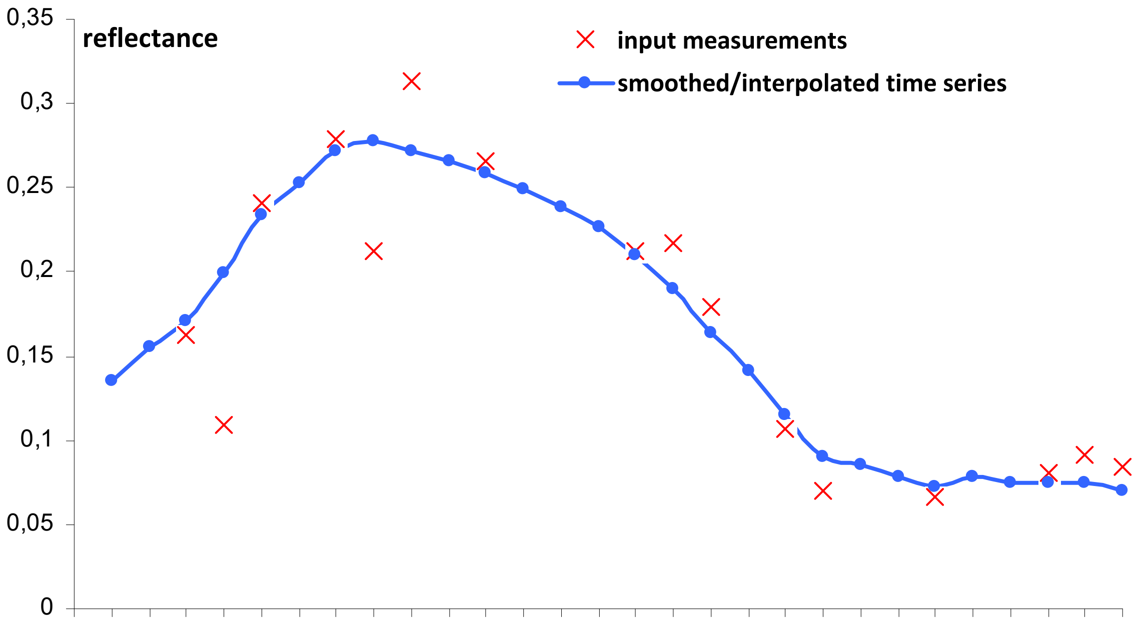
Time series reconstruction

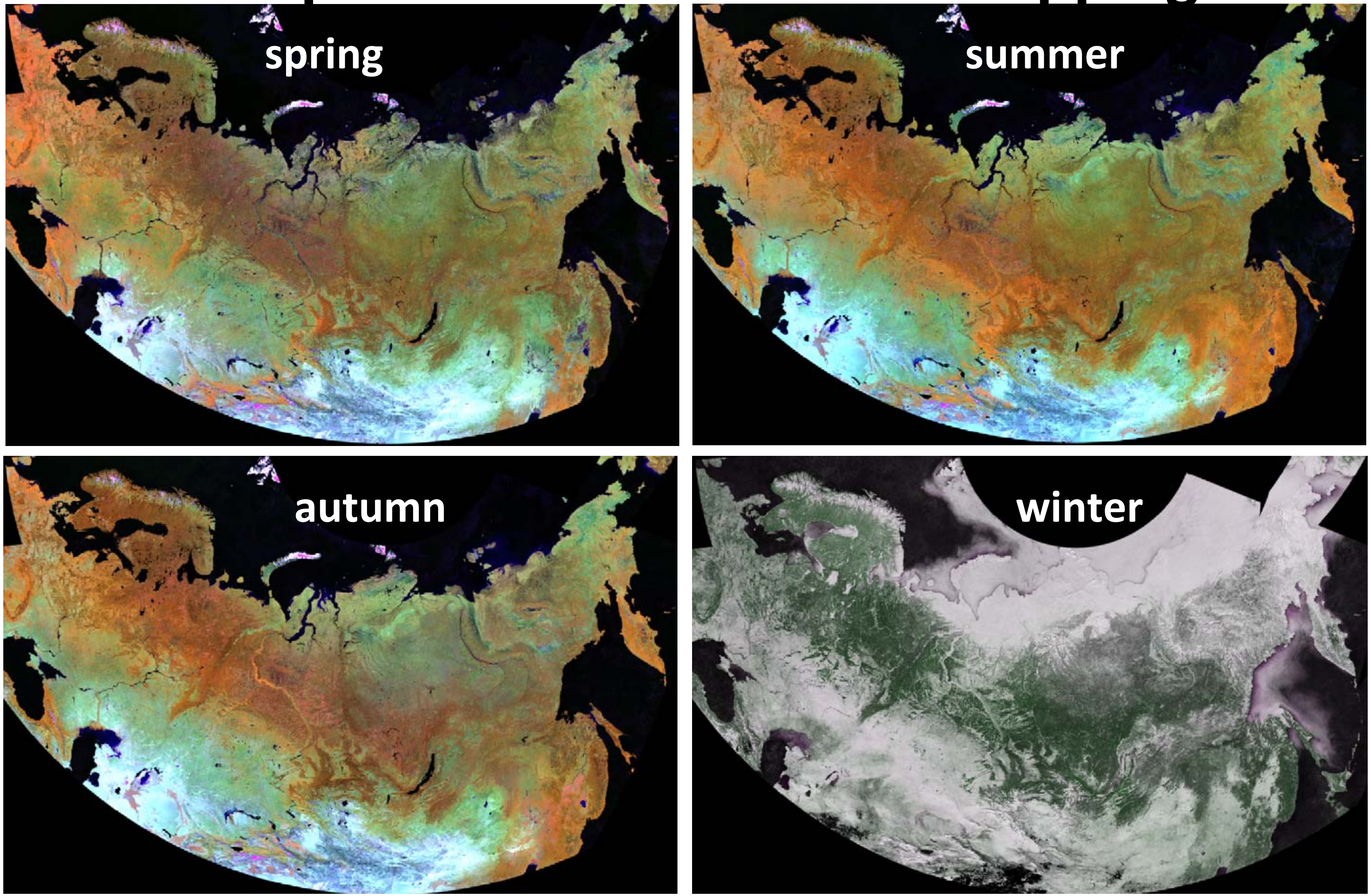
⇩

Cloud-free Image compositing

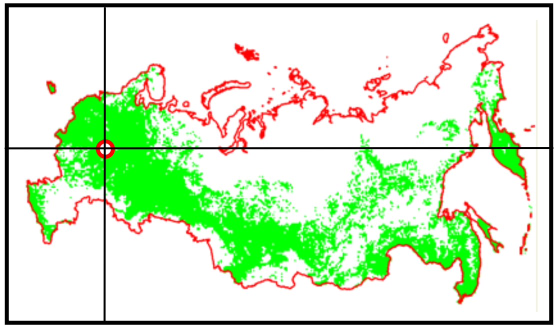


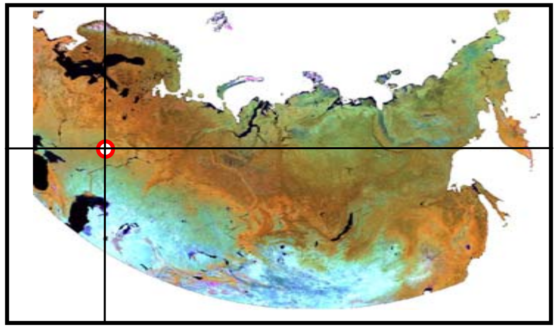


MODIS derived seasonal cloud-free image composites for land cover mapping



LAGMA : Locally Adaptive Global Mapping Algorithm





Local spectral-temporal signatures of classes

Σ_i — Covariation of metrics

$\bar{a}_i$ — Average of metrics

n_i — Number of samples

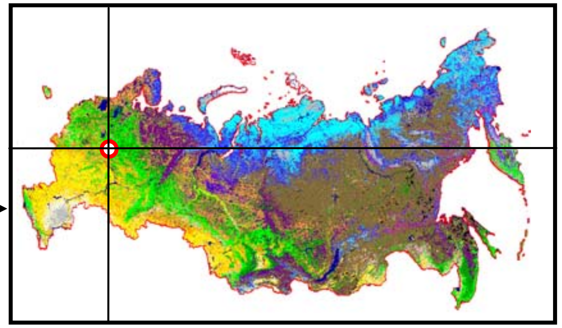
Spectral-temporal MODIS data composites

$\bar{x}$ — Metrics for the pixel

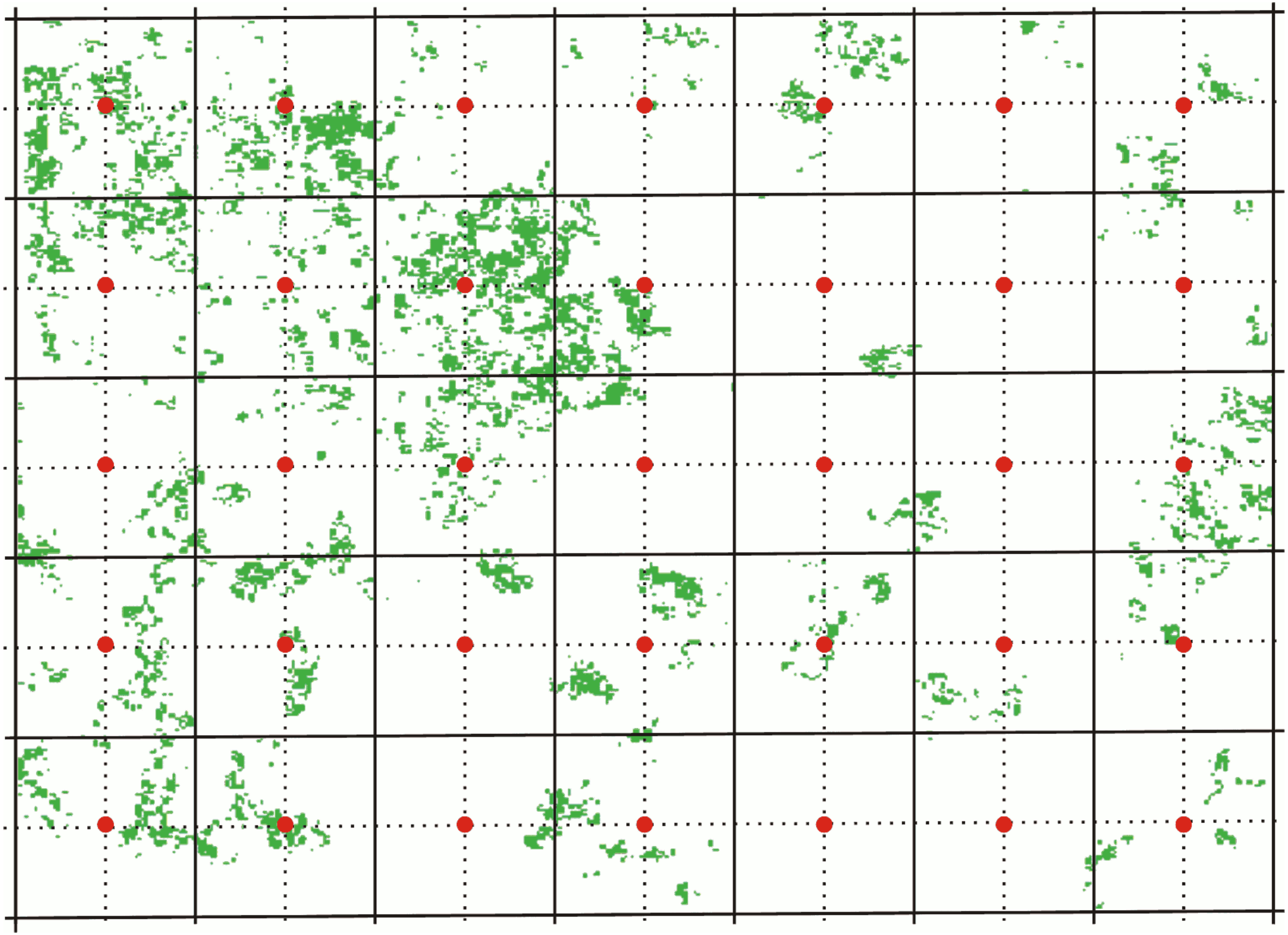
Maximum likelihood classifier

$f_i(\bar{x})$

Probabilities for classes



Classification based on LAGMA method



Land Cover Map

The land cover map for Russia based on MODIS 250 m

Multi-year land cover dynamics

FOREST

Evergreen Dark Needle-leaf
Forest ecosystems consisting of spruce (picea), fir (abies) and siberian pine (pinus sibirica) for at least 80% of the forest canopy.

Evergreen Light Needle-leaf
Forest ecosystems consisting of pine (pinus sylvestris) for at least 80% of the forest canopy.

Broadleaf
Forest ecosystems consisting of birch (betula), aspen (populus tremula), oak (quercus), tilia, ash (fraxinus), maple (acer), elm (ulmus) for at least 80% of the forest canopy.

Mixed with Needle-leaf Majority
Forest ecosystems consisting of the needle-leaf species for 60% to 80% and the broadleaf species for 20% to 40% of the forest canopy.

Mixed
Proportions of the needle-leaf and the broadleaf species in the forest canopy are approximately equal (40% to 60%).

Mixed with Broadleaf Majority
Forest ecosystems consisting of the broadleaf species for 60% to 80% and the needle-leaf species for 20% to 40% of the forest canopy.

Deciduous Needle-leaf
Forest ecosystems consisting of larch (larix) for at least 80% of the forest canopy.

Sparse Deciduous Needle-leaf
Single trees of sparse tree canopy of larch (larix) having less than 20% density.

GRASSLANDS AND SHRUBLANDS

Humid Grasslands
Grasslands having vegetative season over 5 months long and sufficient humidification. The species composition consists mainly of perennial plant, particularly of cereals and sedges. Forest and shrub canopy area is less than 20%.

Steppe
Herbaceous canopy is mainly composed of drought-resistant perennial bunchgrass, including mat-grass, fescue, mugwort and others. There is also a diversity of steppe shrubs and subshrubs, with short-blooming ephemeral and ephemeroid plants.

Evergreen Needle-leaf Shrubs
Scrublands or low forest of mountain pine (pinus pumila).

Broadleaf Deciduous Shrubs
Scrublands or low forest of deciduous species, including dwarf birch (Betula nana), polar willow (Salix polaris) and others;

TUNDRA

Prostrate Shrub
Dry tundra with sparse vegetation consisting mainly of Alpine and Arctic dwarf-shrub species less than 15 cm high. Moss, lichen and forbs can also be found.

Sedge
Tundra consisting of various herbs and mosses vegetating on wet soil and making up continuous cover. Dwarf-shrubs up to 40 cm high can also be found.

Shrub
Shrubs including dwarf birch (betula nana), willow (salix) over 40 cm high, sometimes mixed with juniperus, высотой более 40 см, иногда с примесью можжевельника, ольхи или кедрового стланика.

WETLANDS

Peatlands
Overhumidified lands covered mainly with moss, lichen, reed and sedge. Sometimes sparse tree canopy (up to 20%) can be found.

Riparian Vegetation
Hydrophilic, periodically flooded herbaceous, shrub and forest vegetation along the coastlines.

OTHER VEGETATION

Recent Burns
Tree cover or tundra seriously damaged by fire or dead.

Croplands
Arable lands regularly cultivated for at least 5 recent years.

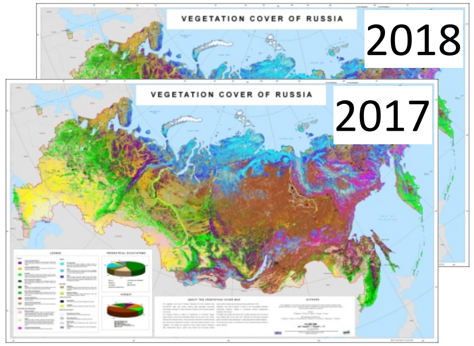
NON-VEGETATED AREAS

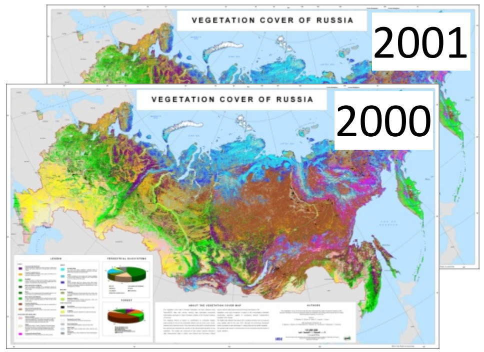
Permanent Ice and Snow
Land covered by ice or snow for the whole year.

Bare Soil and Rock
Lands having total vegetation canopy less than 20%.

Water Bodies
Open water bodies including seas, lakes, reservoirs and rivers.

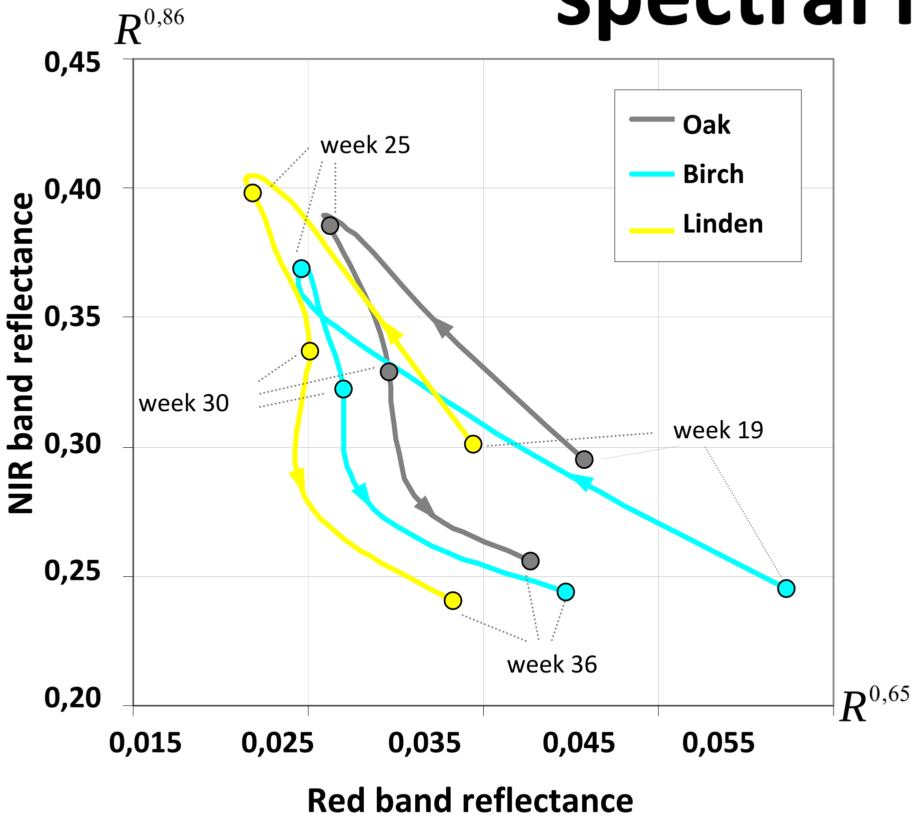
Urban Area
Populated areas, roads, industries and other anthropogenic objects.

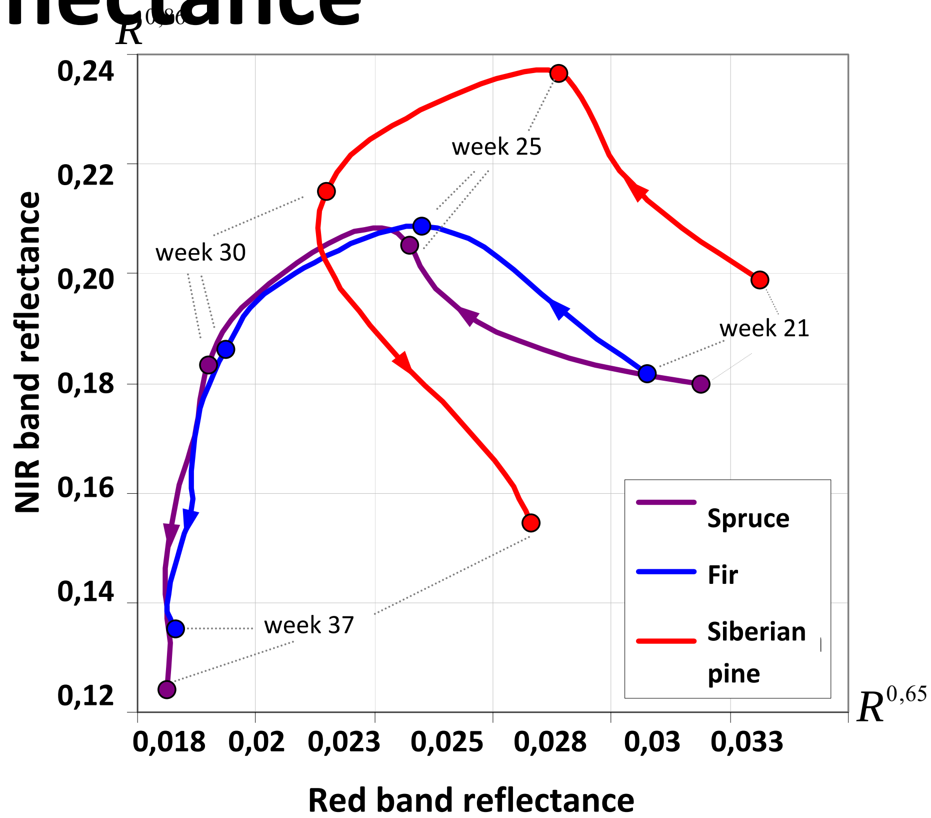




Annual mapping of 23 land cover classes since the year 2000 based on 250 m MODIS data

Phenological dynamics of forest cover spectral reflectance

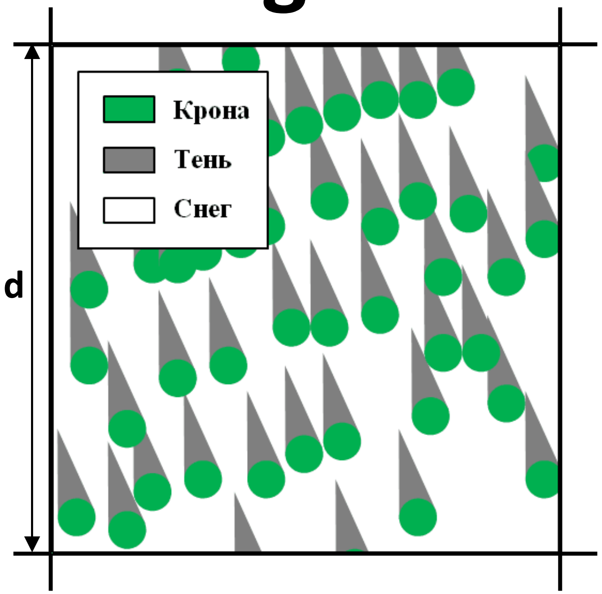




Phase trajectories for forest cover with different tree species in a red-NIR MODIS band reflectance space; movement along the curve corresponds to mean reflectance dynamics during a season

The forest cover is classified considering dominant tree species using seasonal time-series of MODIS data

Growing stock volume mapping over Russia

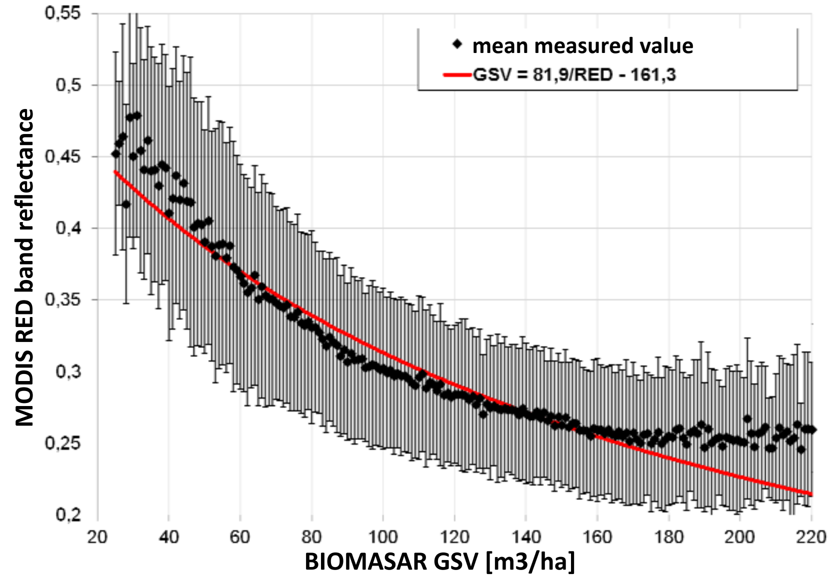


Sc – snow area

Sk – crown area

St – shadow area

h – tree height; n – number of trees



winter composite image reflectance-GSV relationship for pine forests in Russia

Pixel RED band reflectance:

$$R = f\left(S_c, S_k, S_t\right);$$

$$S_c = d^2 - S_k - S_t,$$

$$S_k = f_1\left(n\right), S_t = f_2\left(n, h\right),$$

$$R = f_3(n, h);$$

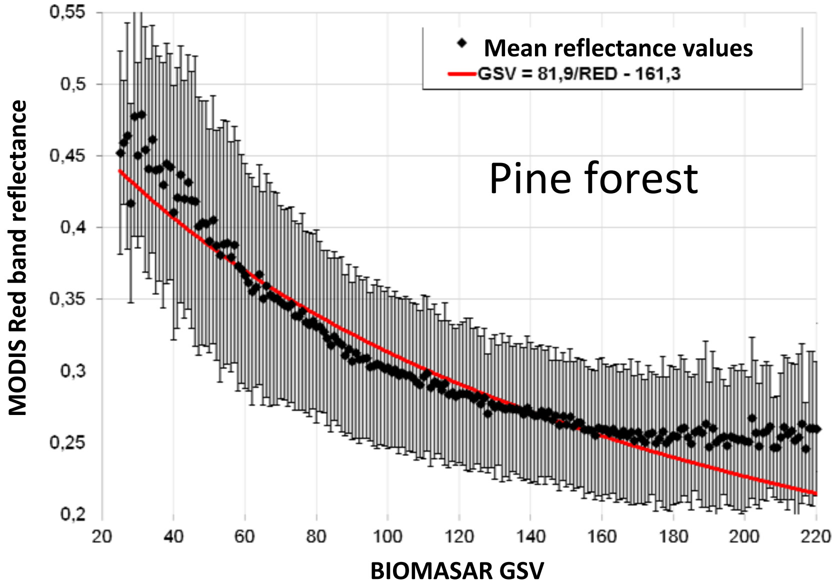
Pixel GSV:

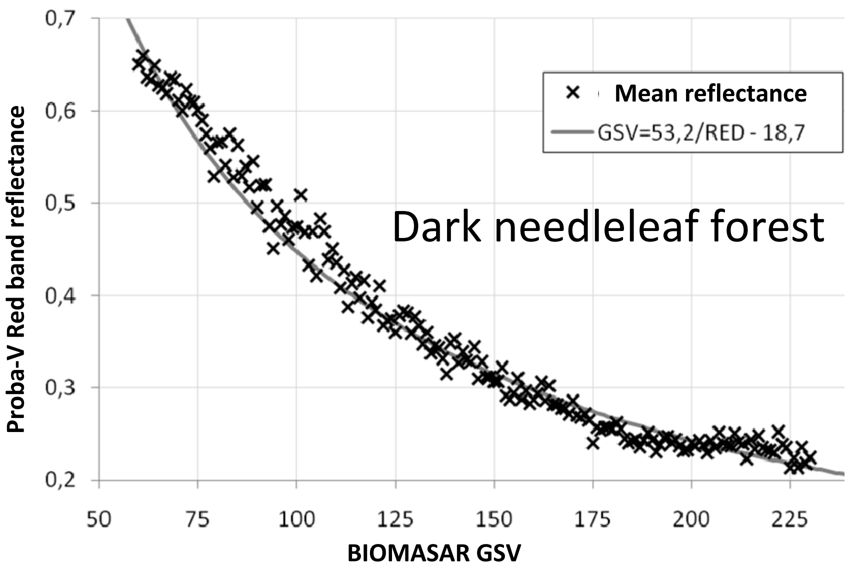
$$GSV\left[m^3 / ha\right] = f_4(n, h)$$

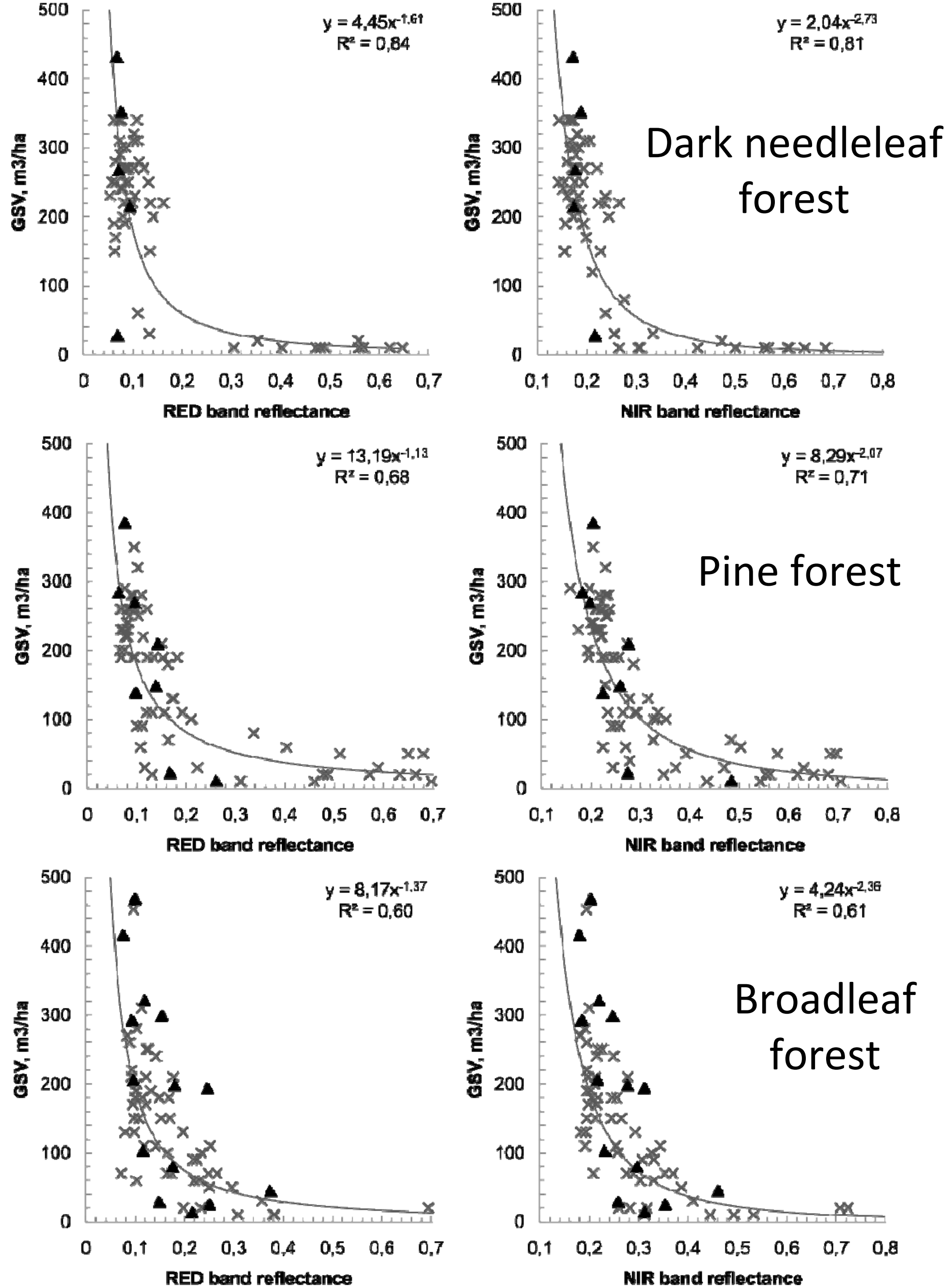
Model:

$$GSV\left[m^3 / ha\right] \sim 1/R$$

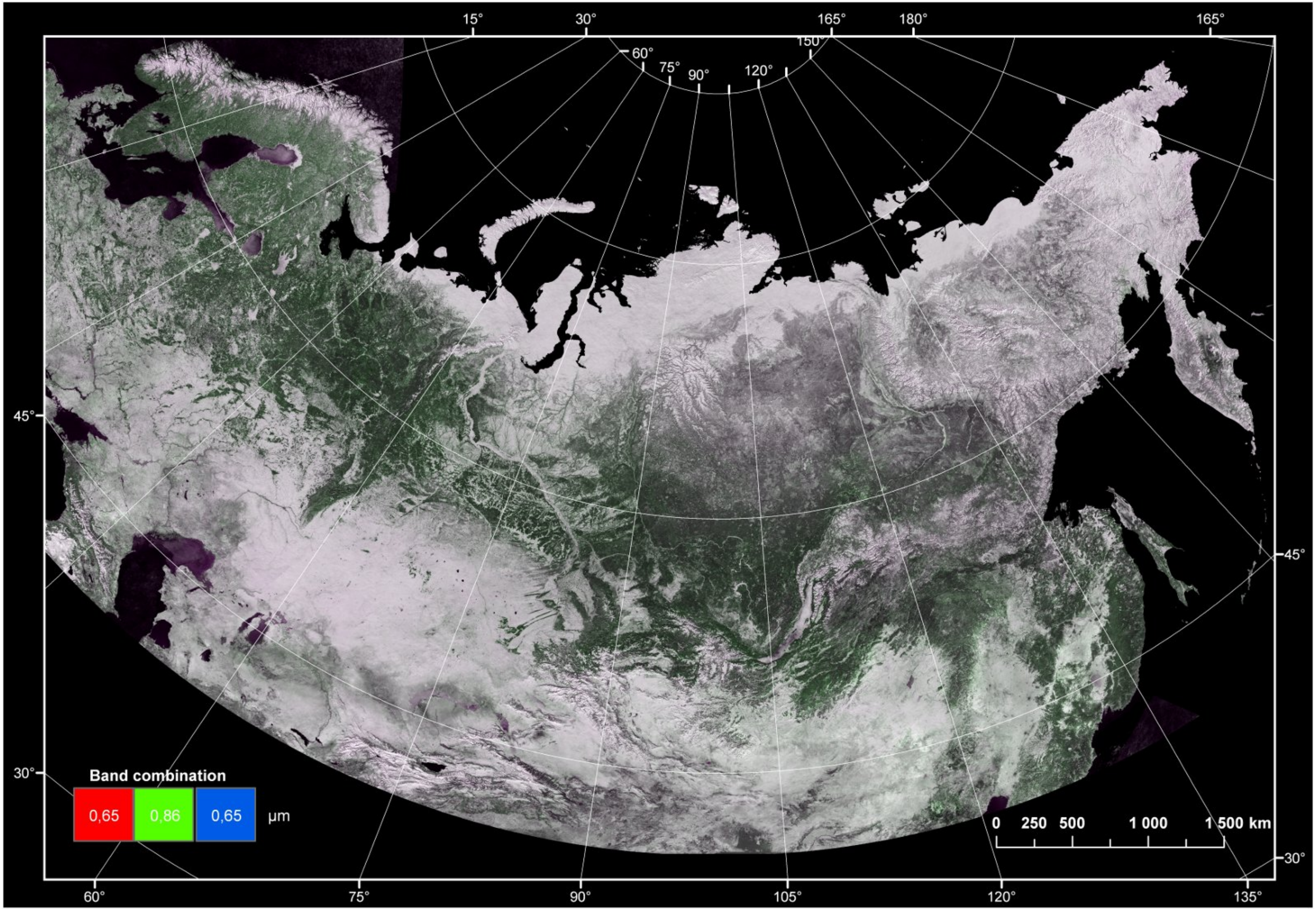
GSV-reflectance relationship modeling







Composite image of snow-covered land

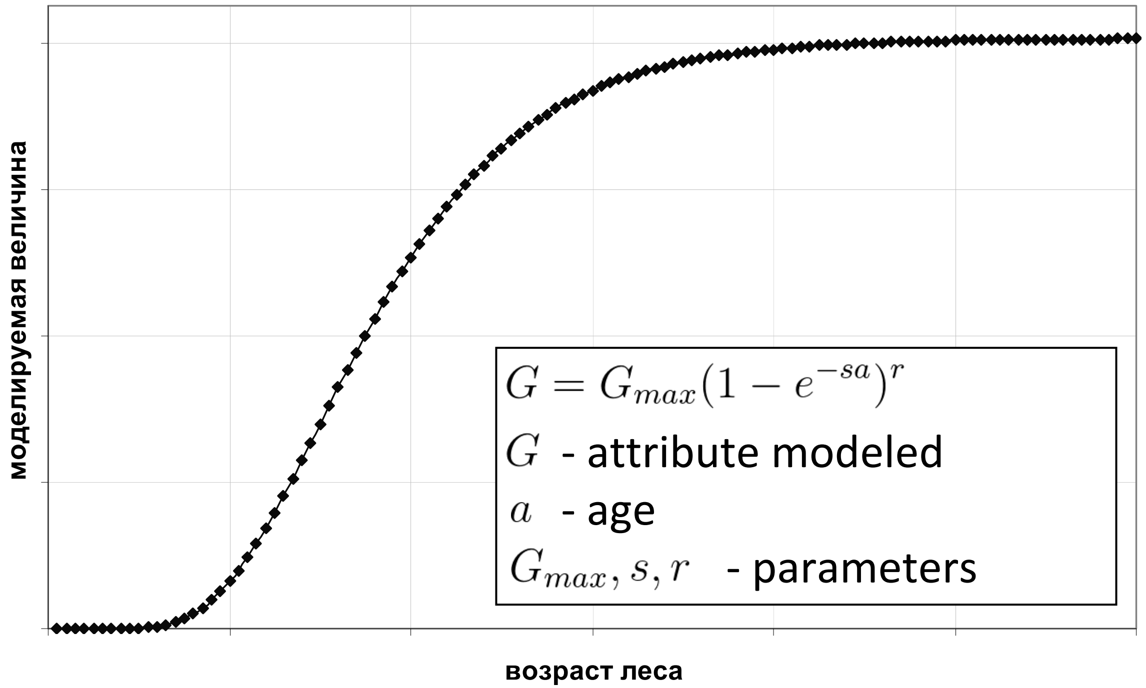


Annual forest GSV retrieval based on MODIS data

Forest dynamics model parameterization based on annual GSV measurements

Annual GSV maps time series

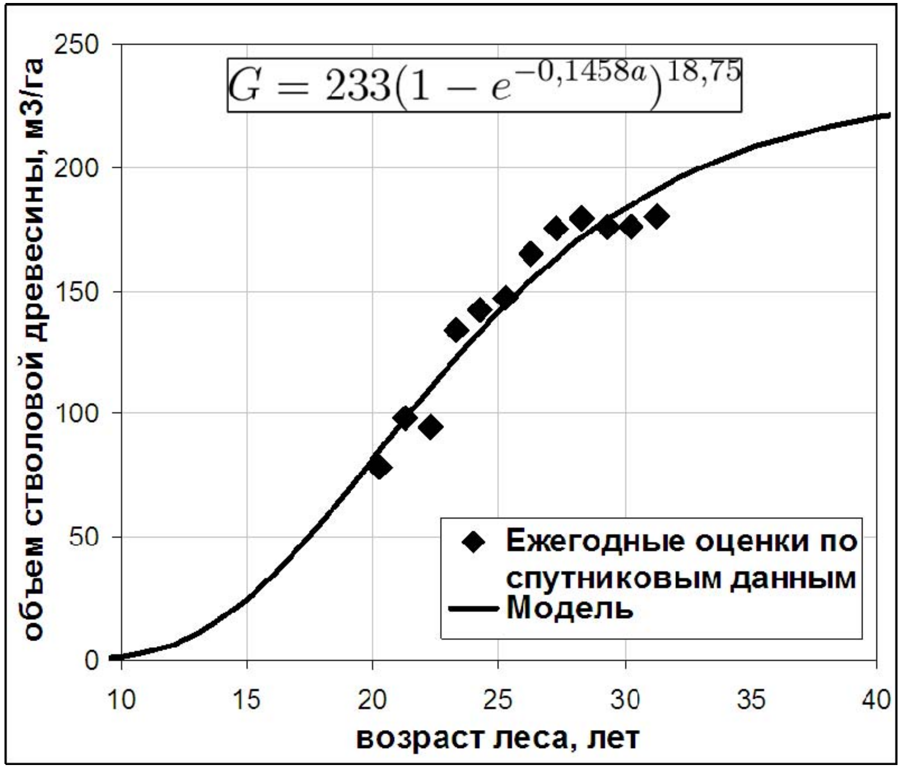
Моделирование динамики биофизических характеристик лесов функцией Ричардса - Чепмена (F. Richards, 1959, D. Chapman, 1961)



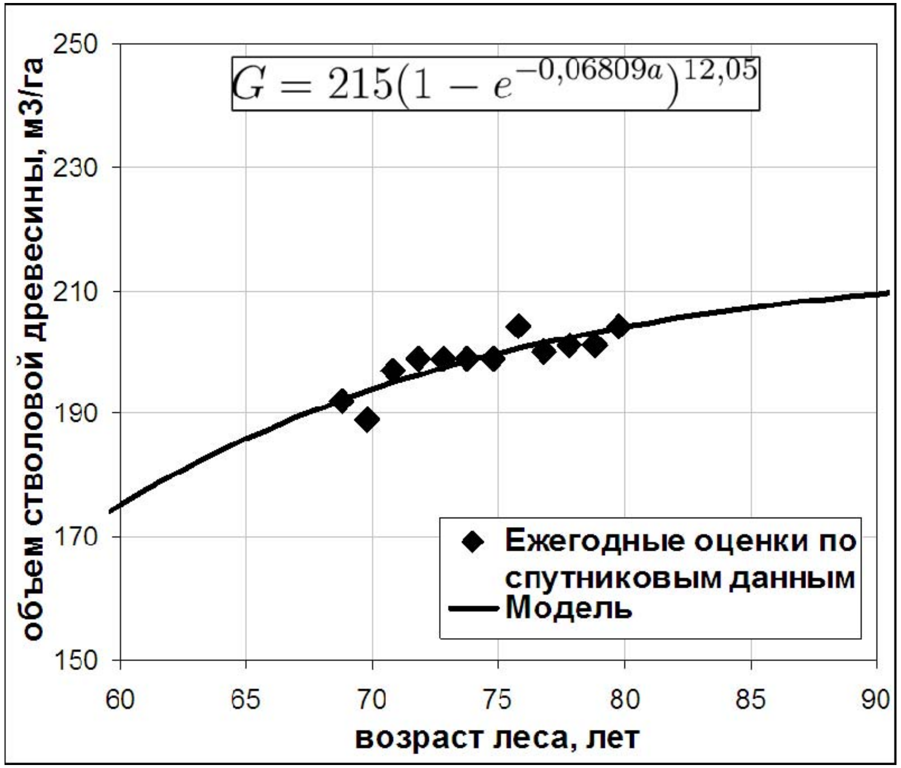
$$
\begin{cases}
G_{2001} = G_{\max}(1 - e^{-sa})^r \\
G_{2002} = G_{\max}(1 - e^{-s(a+1)})^r \\
\vdots \\
G_{2013} = G_{\max}(1 - e^{-s(a+12)})^r
\end{cases}
\longrightarrow
\quad s, r
$$

a - age

Forest dynamics model parameterization based on annual GSV measurements

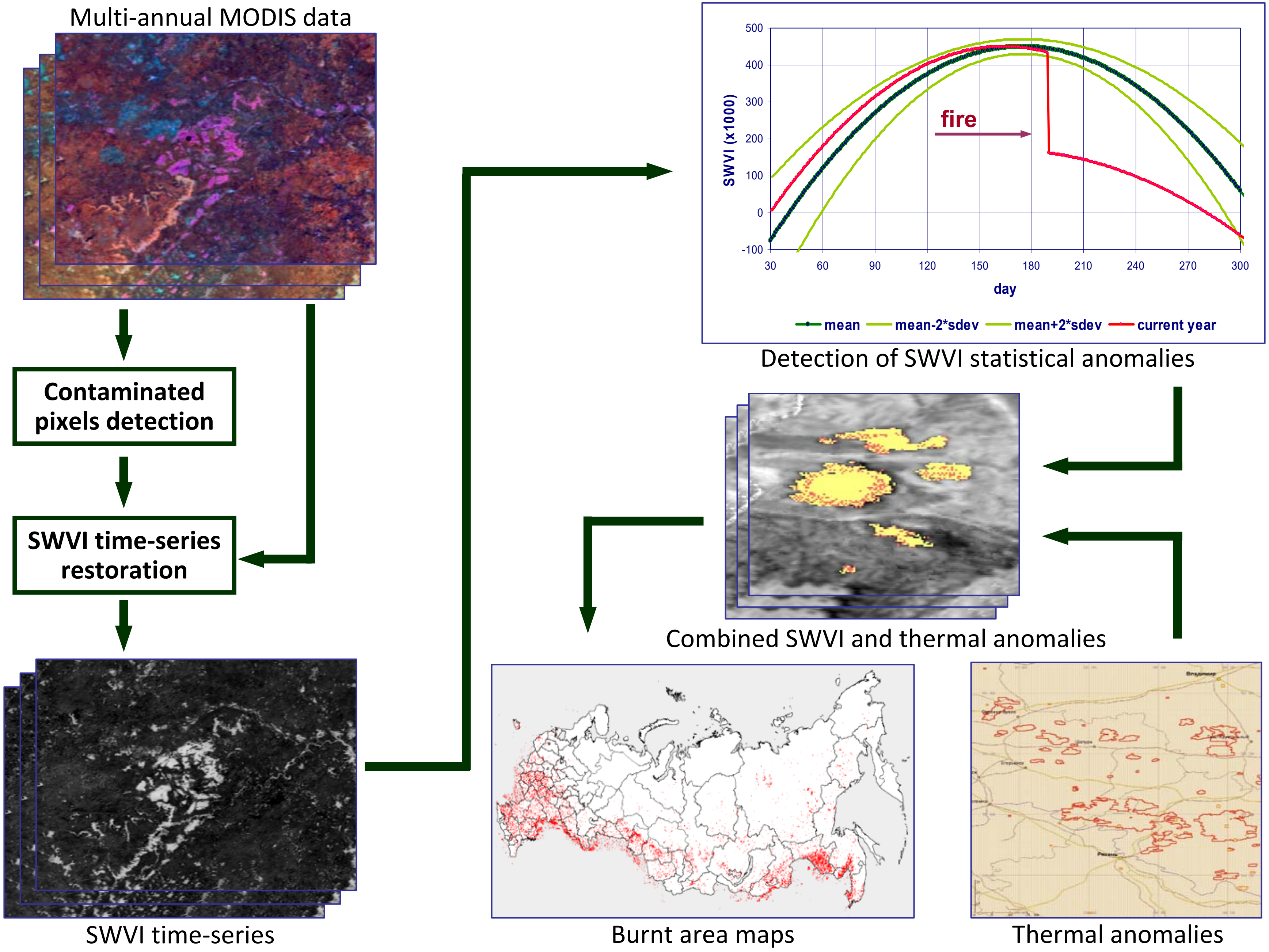


GSV dynamics for birch in European Russia, forest age for 2012 – 30 years

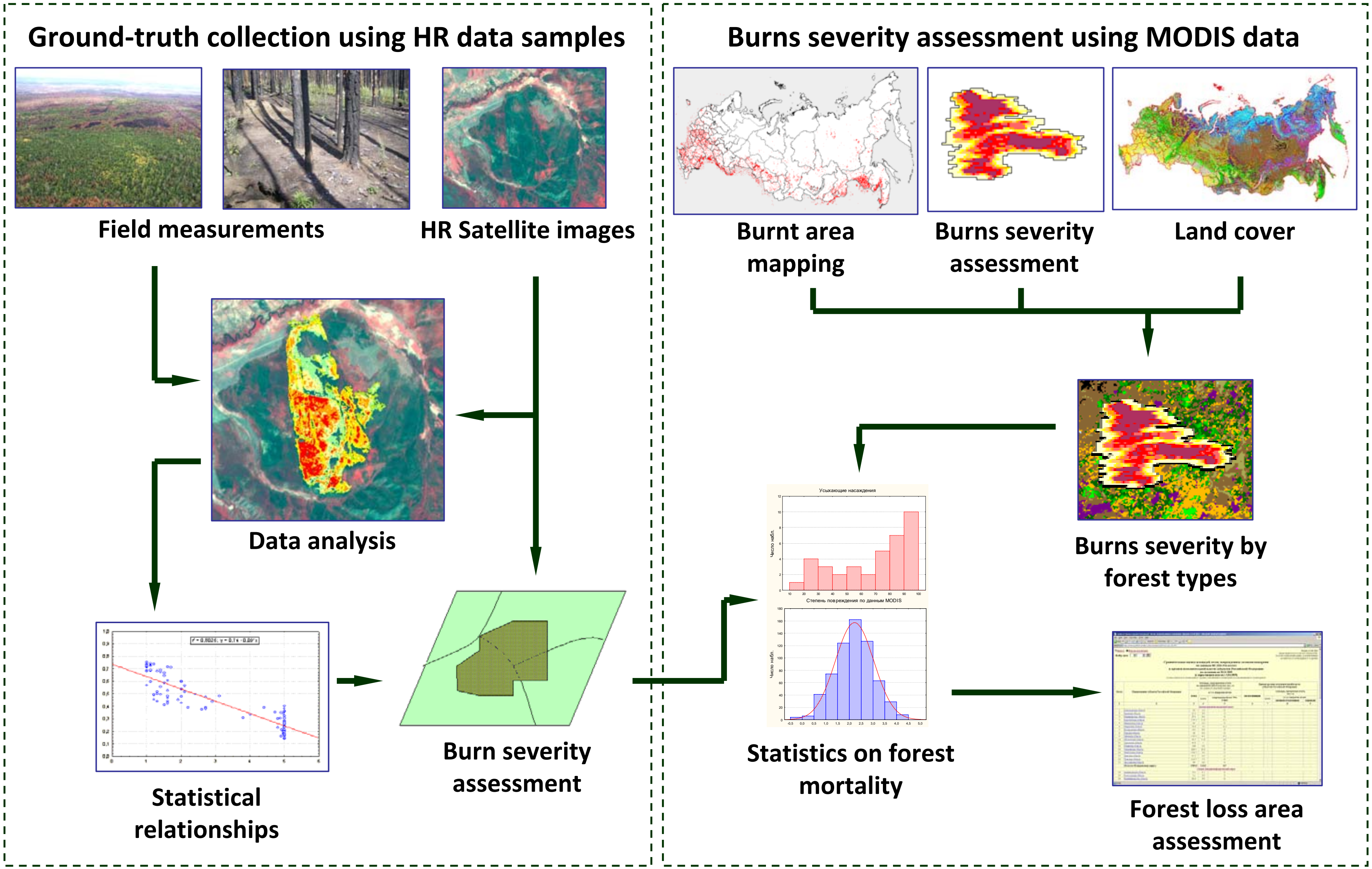


GSV dynamics for pine in Altai federal subject, forest age for 2012 – 80 years

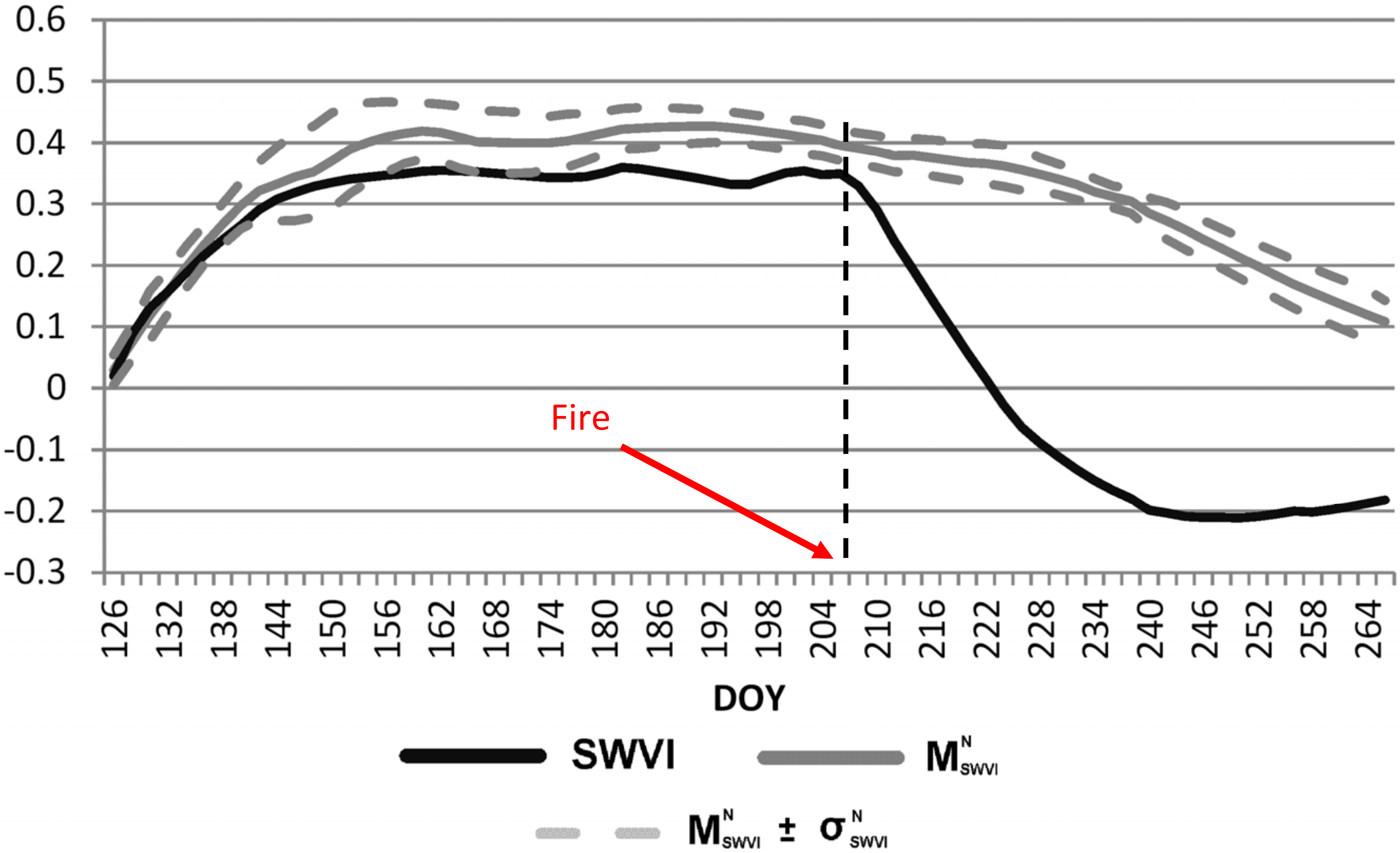
Burnt area mapping using MODIS



Forest burn severity assessment

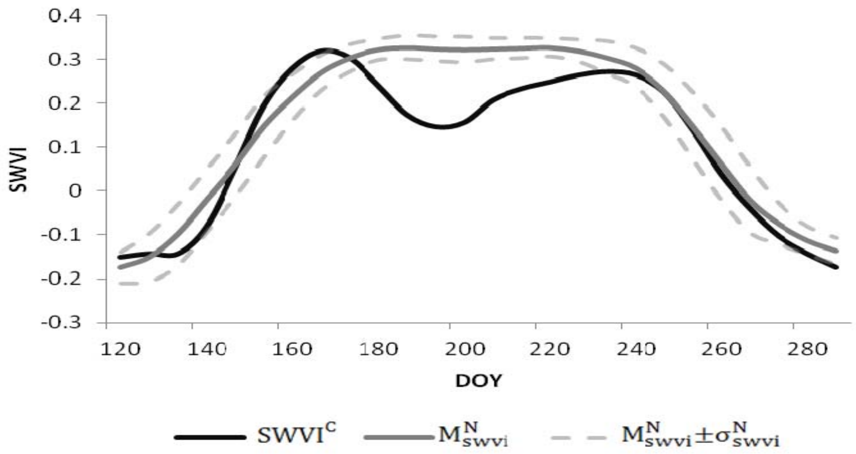


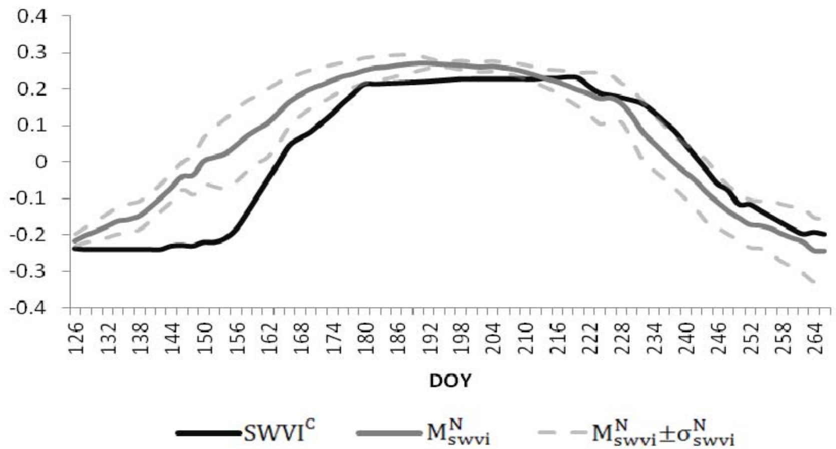
Detection of burnt forests by deviation of SWVI seasonal profile from statistical norm



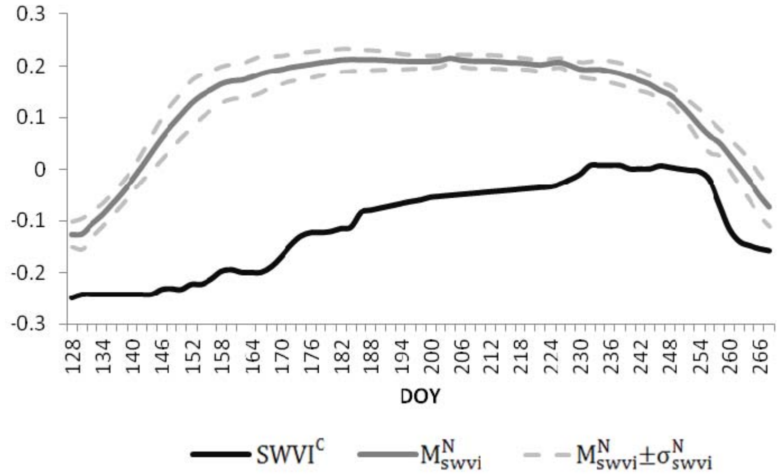
Classification of burnt forest by sustainability of SWVI changes

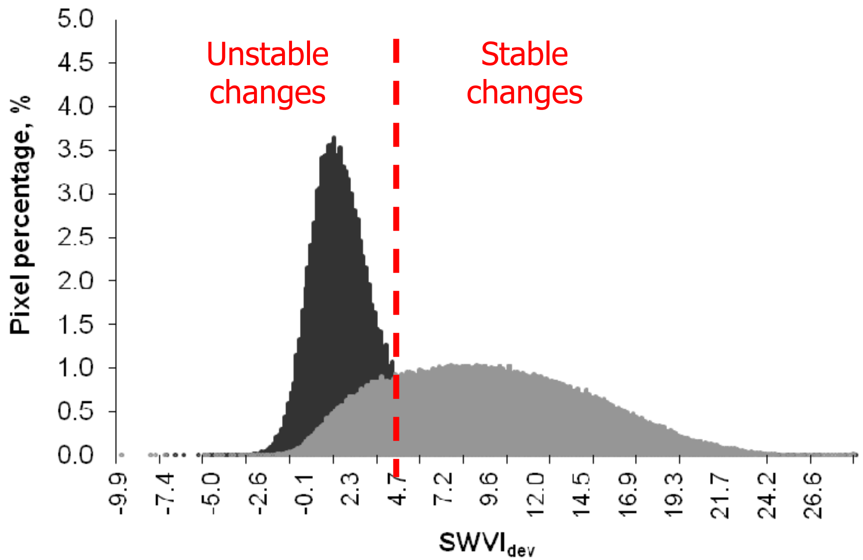
Examples of SWVI unstable deviation from the statistical norm





An example of SWVI stable deviation from the statistical norm



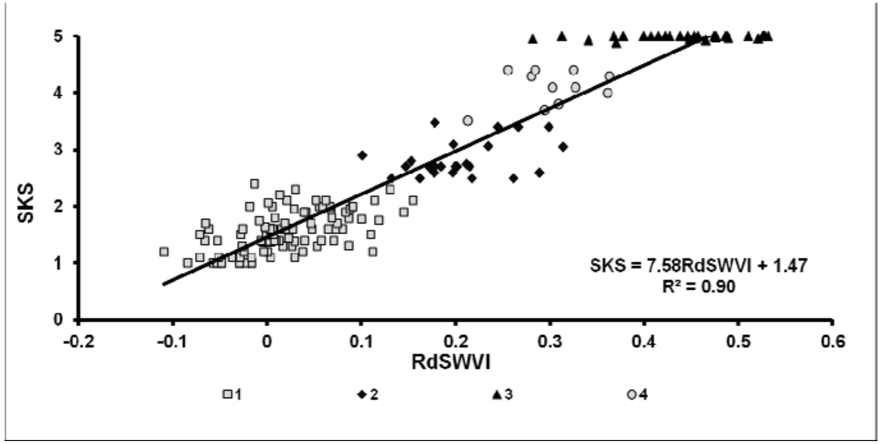


Forest burn severity assessment using EO data

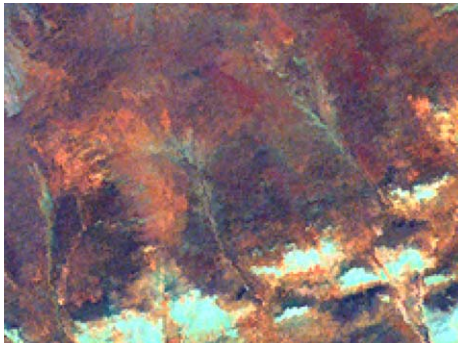
RdSWVI (relative difference short wave vegetation index) has shown best correlation with burn severity

$$RdSWVI = \frac{SWVI_{pre} - SWVI_{post}}{\sqrt{SWVI_{pre} + 1}} \qquad SWVI = \frac{R_{nir} - R_{swir}}{R_{nir} + R_{swir}}$$

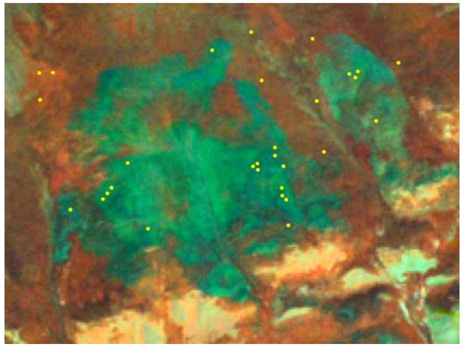
where Rnir and Rswir are near- and short-wave-infrared spectral channels



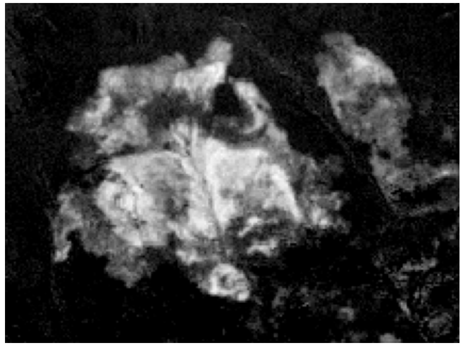
Relationship between trees mortality index (SKS) and RdSWVI



Pre-fire satellite imagery

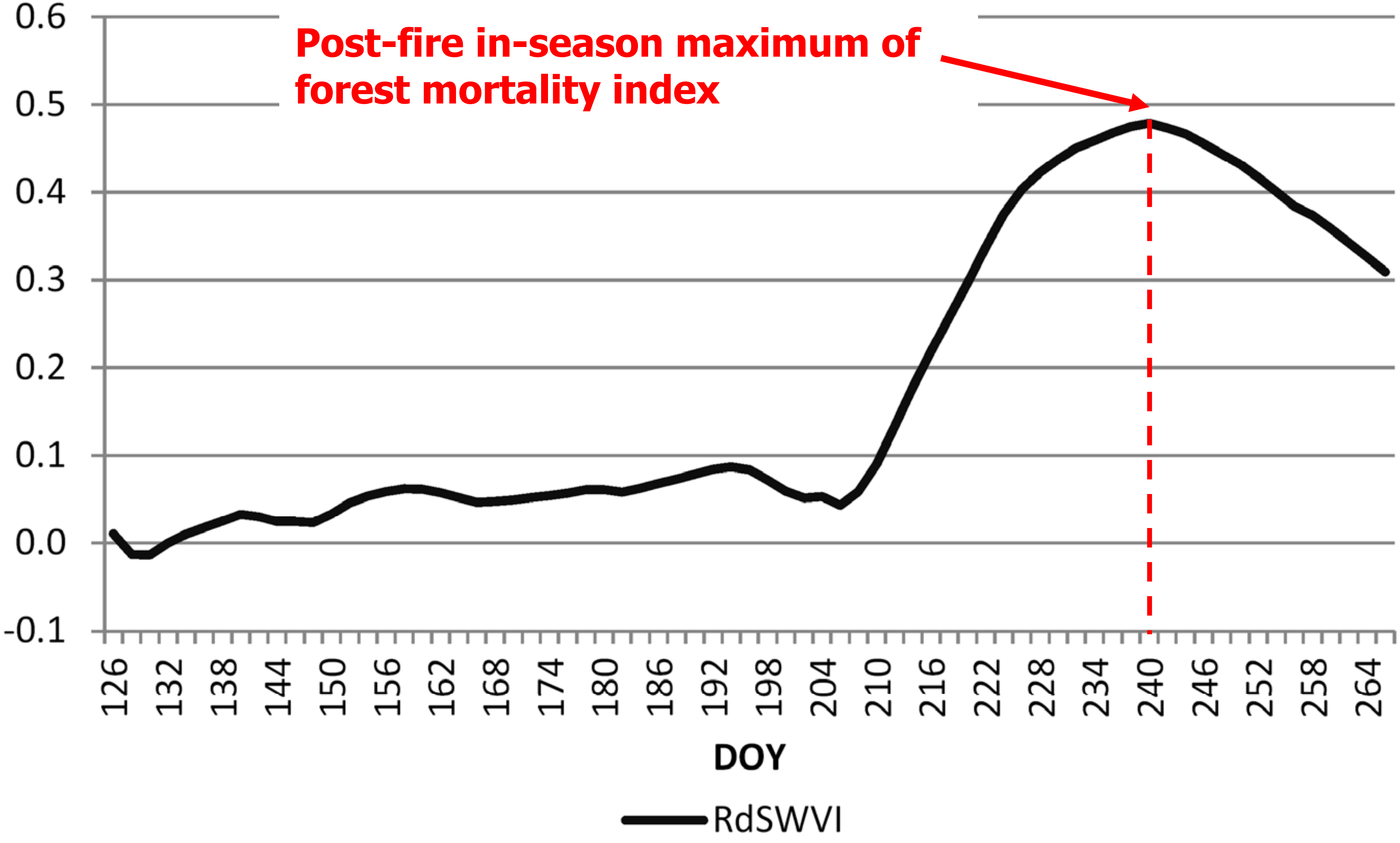


Post-fire satellite imagery with field test sites

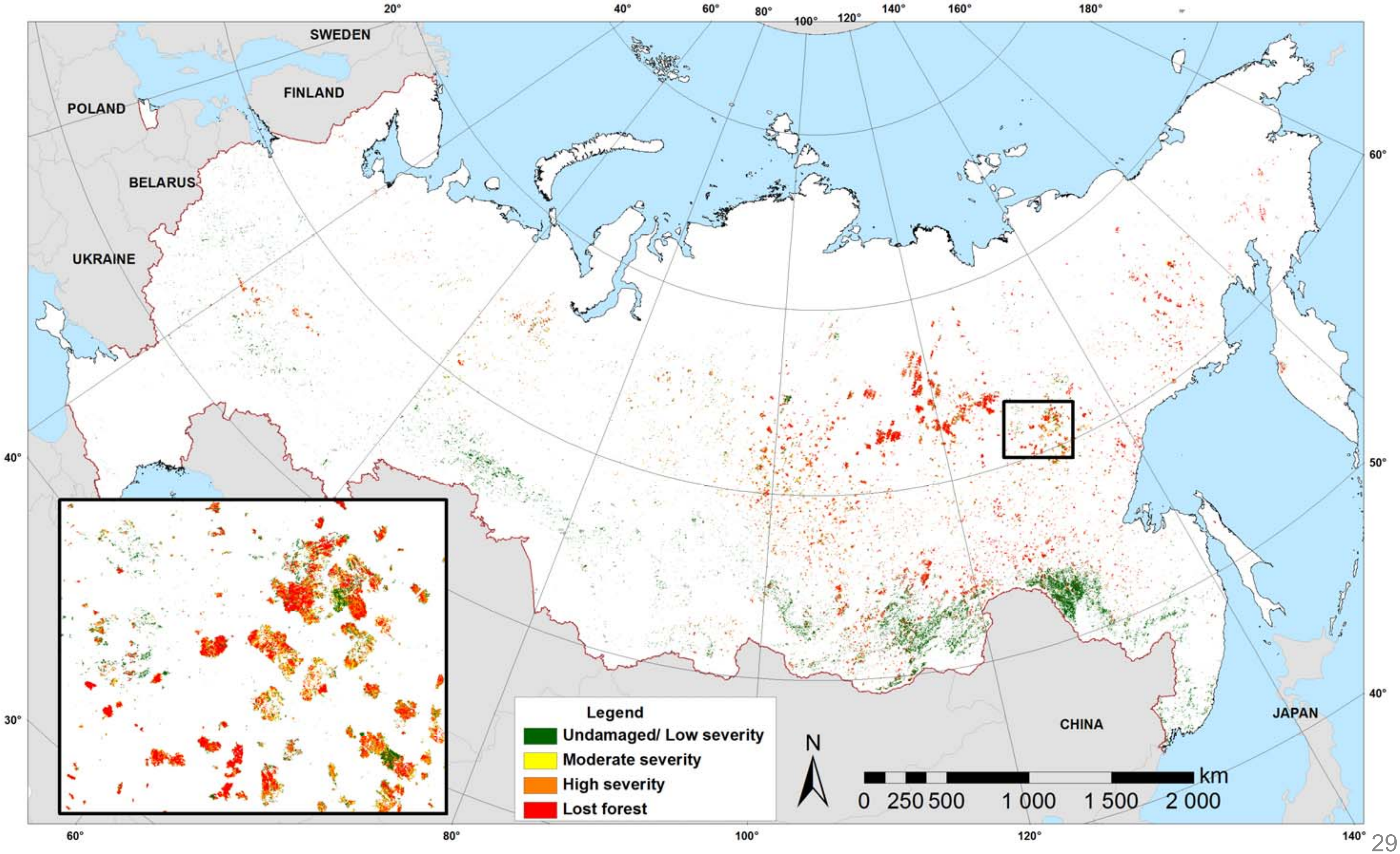


RdSWVI index imagery

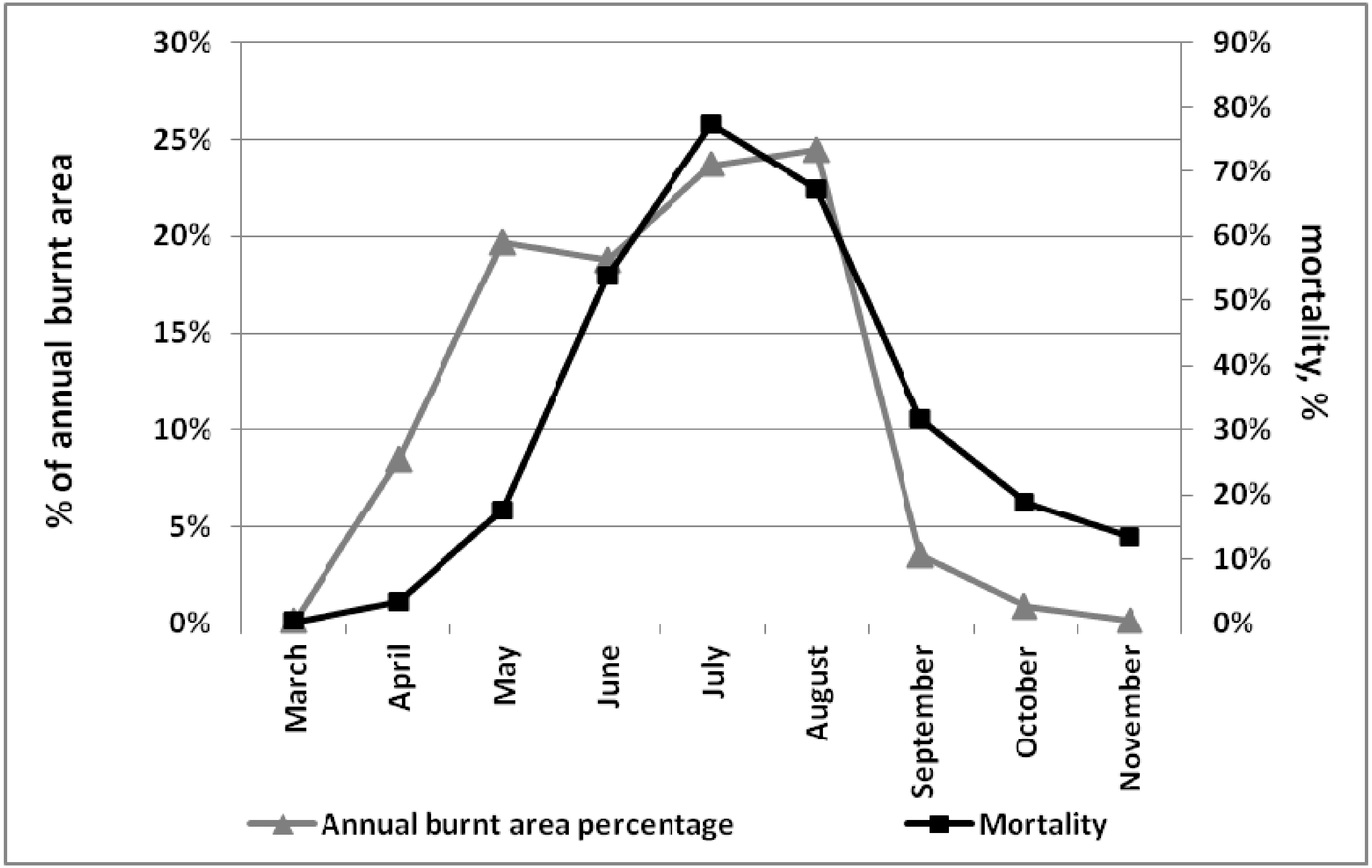
Post-fire RdSWVI temporal dynamics analysis



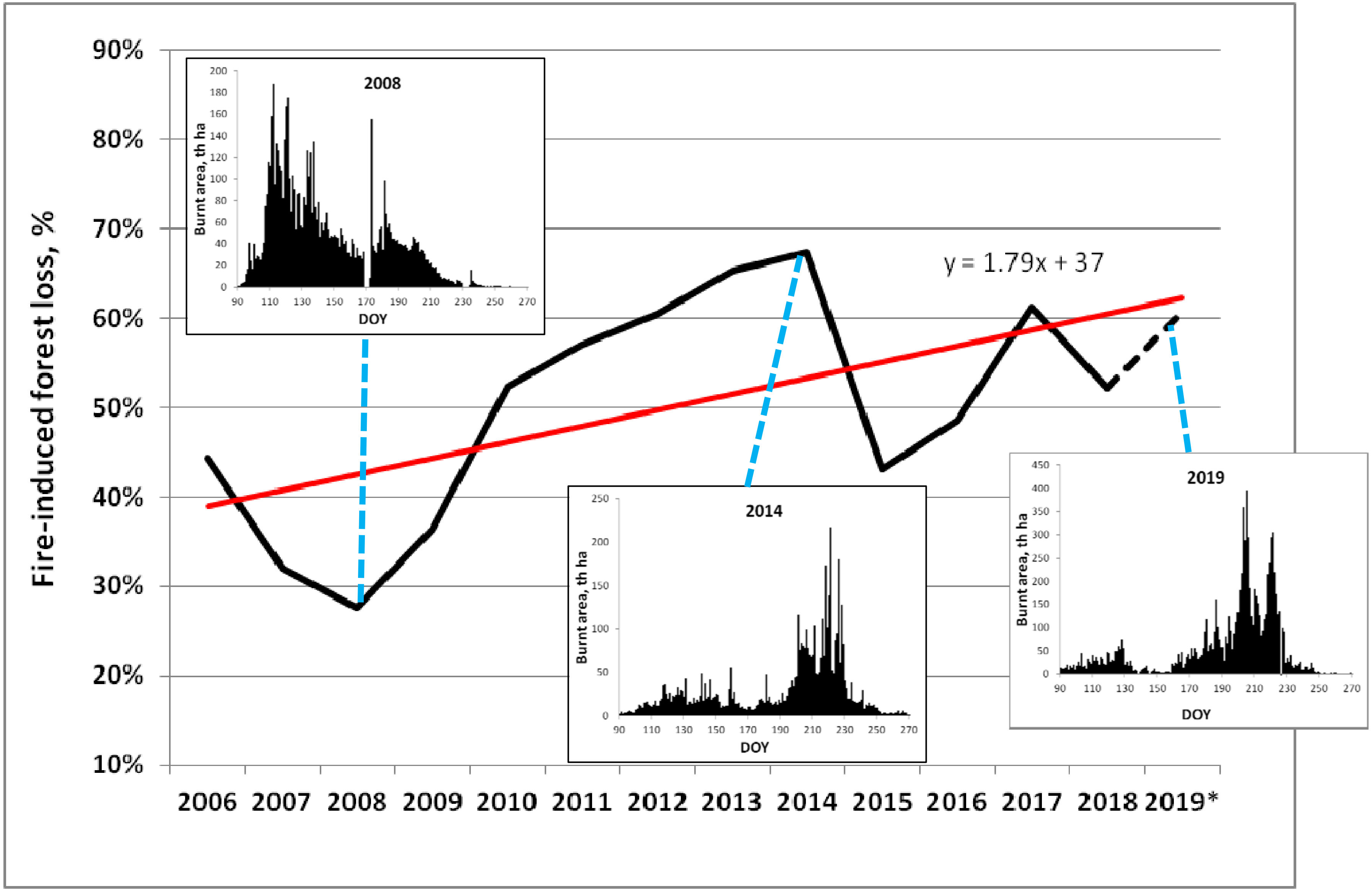
Forest burn severity for years 2006-2018



Seasonal distribution of forest burnt and loss areas over Russia for years 2006-2016

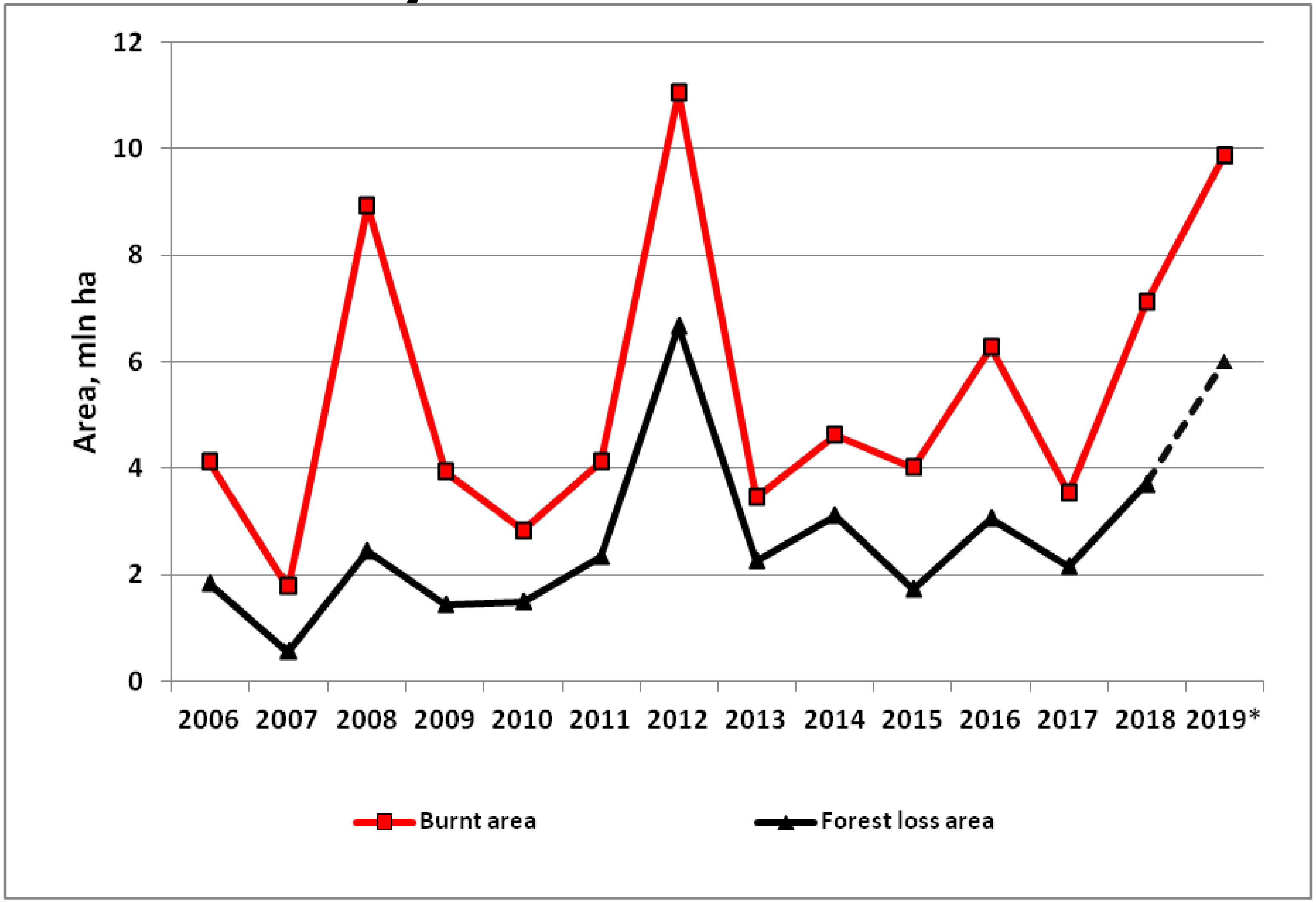


Multi-year changes of fire-induced forest loss



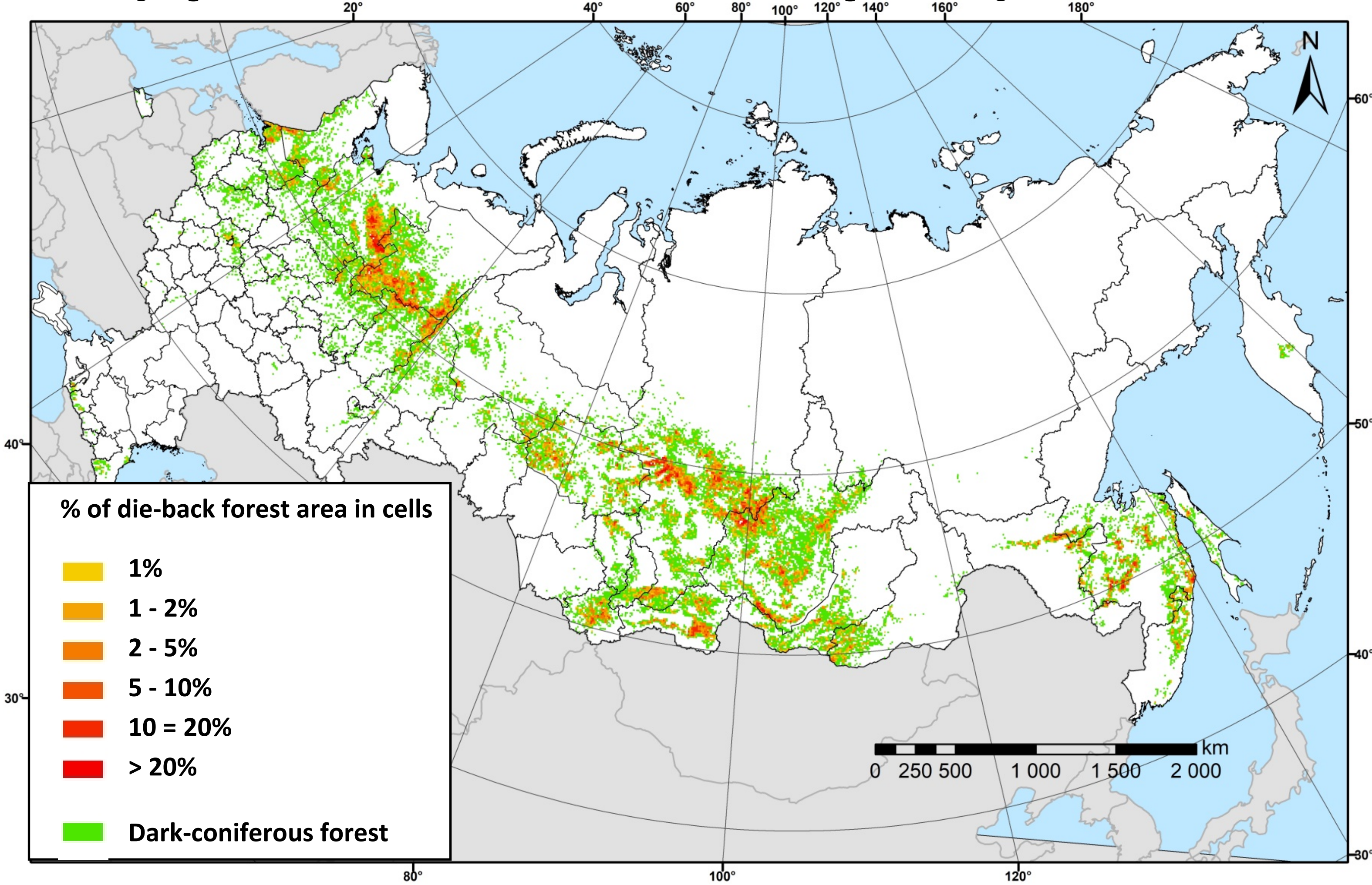
* The forest loss area for 2019 is predicted

Fire-induced forest loss area over Russia for years 2006-2019



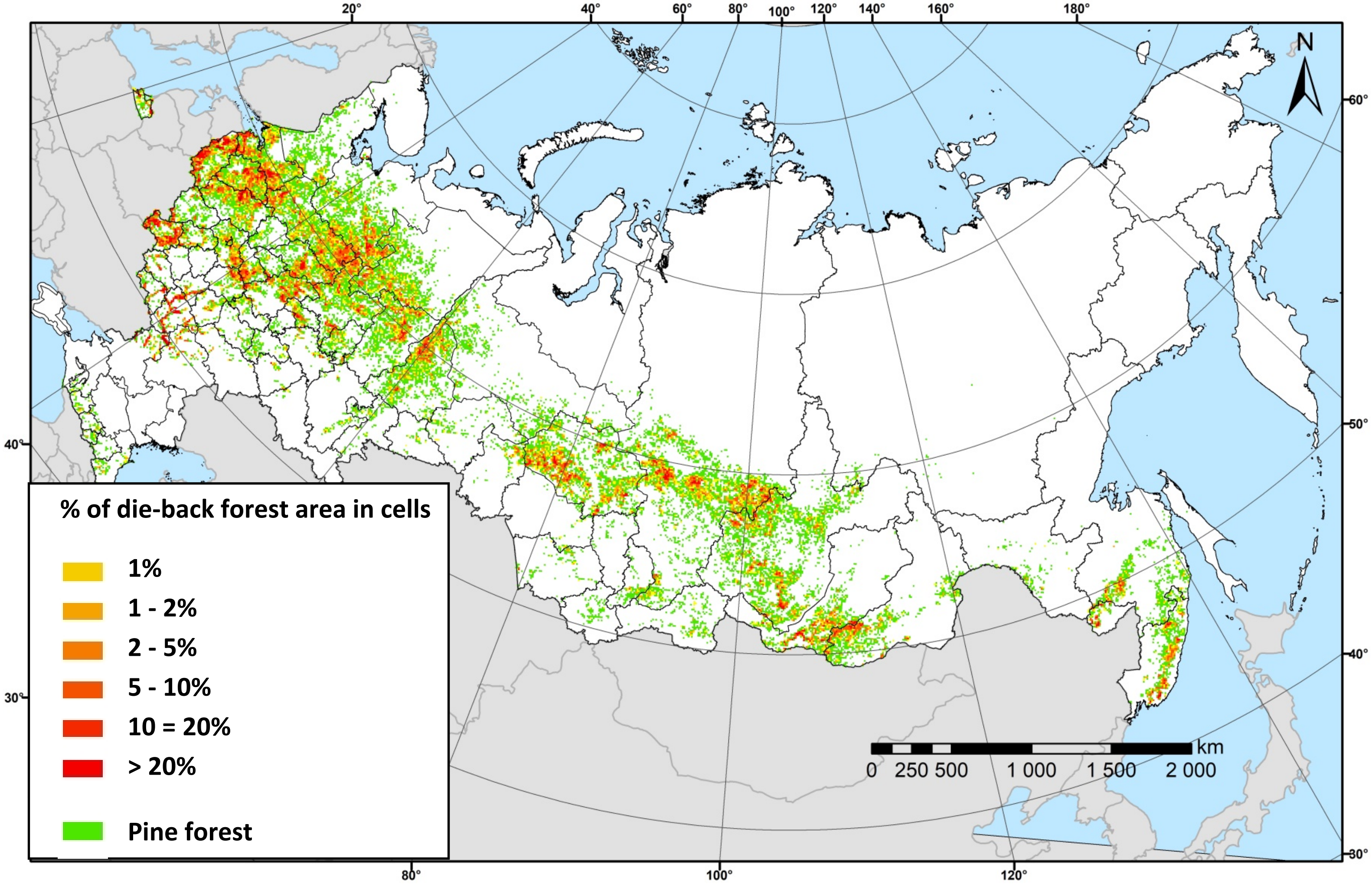
*For 2019, the forecast of the forest loss area is given

Non-fire caused die-back of dark-coniferous (spruce, fir, Siberian pine) forest



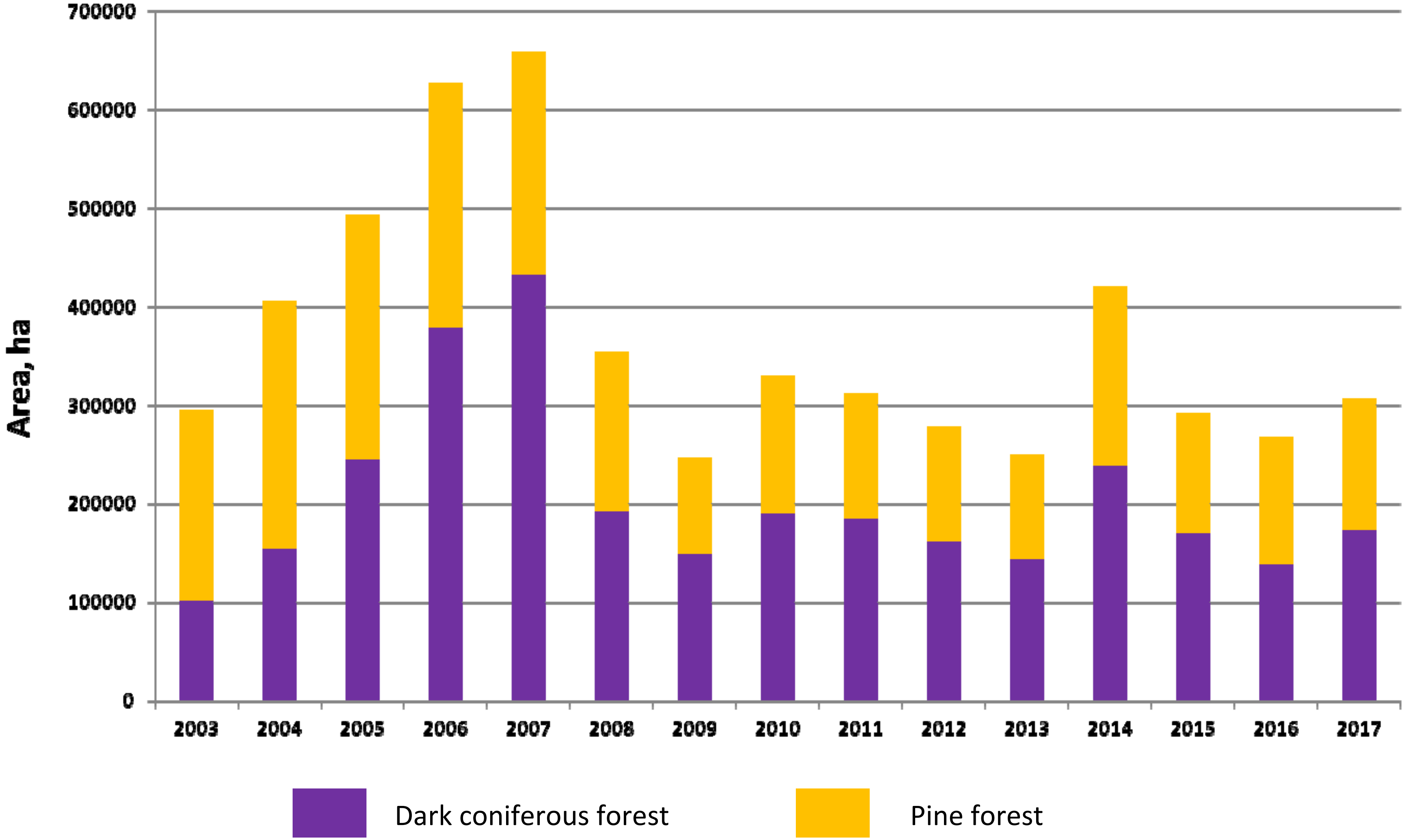
The dark-coniferous forest area of non-fire induced die-back during years 2003-2017 is estimated at $3{,}05 \times 10^6$ ha

Non-fire caused die-back of pine forest



The pine forest area of non-fire induced die-back during years 2003-2017 is estimated at $2,49x10^6$ ha

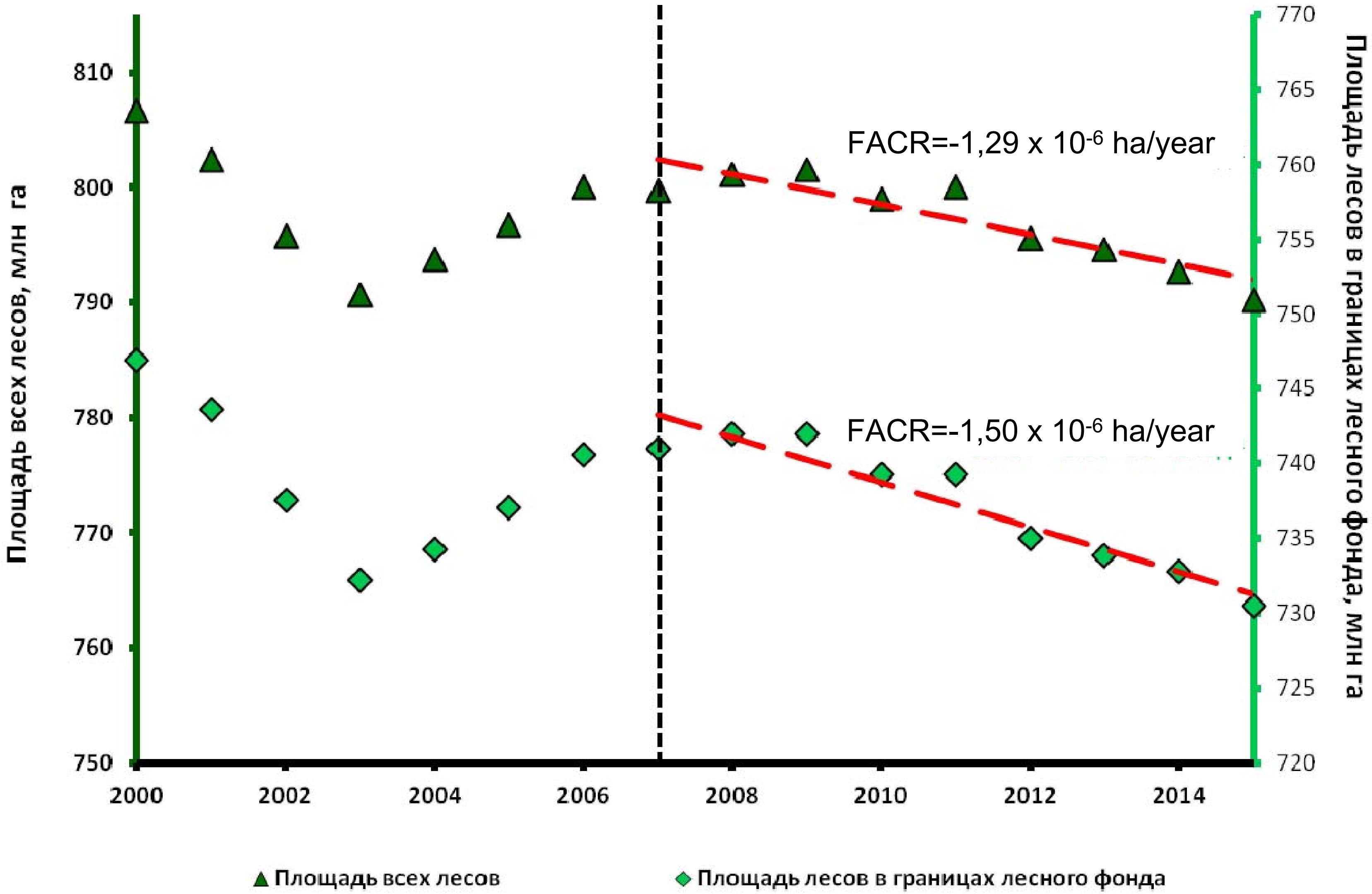
Dynamics of non-fire caused die-back of dark-coniferous and pine forests in Russia



Russian Forest Assessment: RS derived estimates vs. official statistics

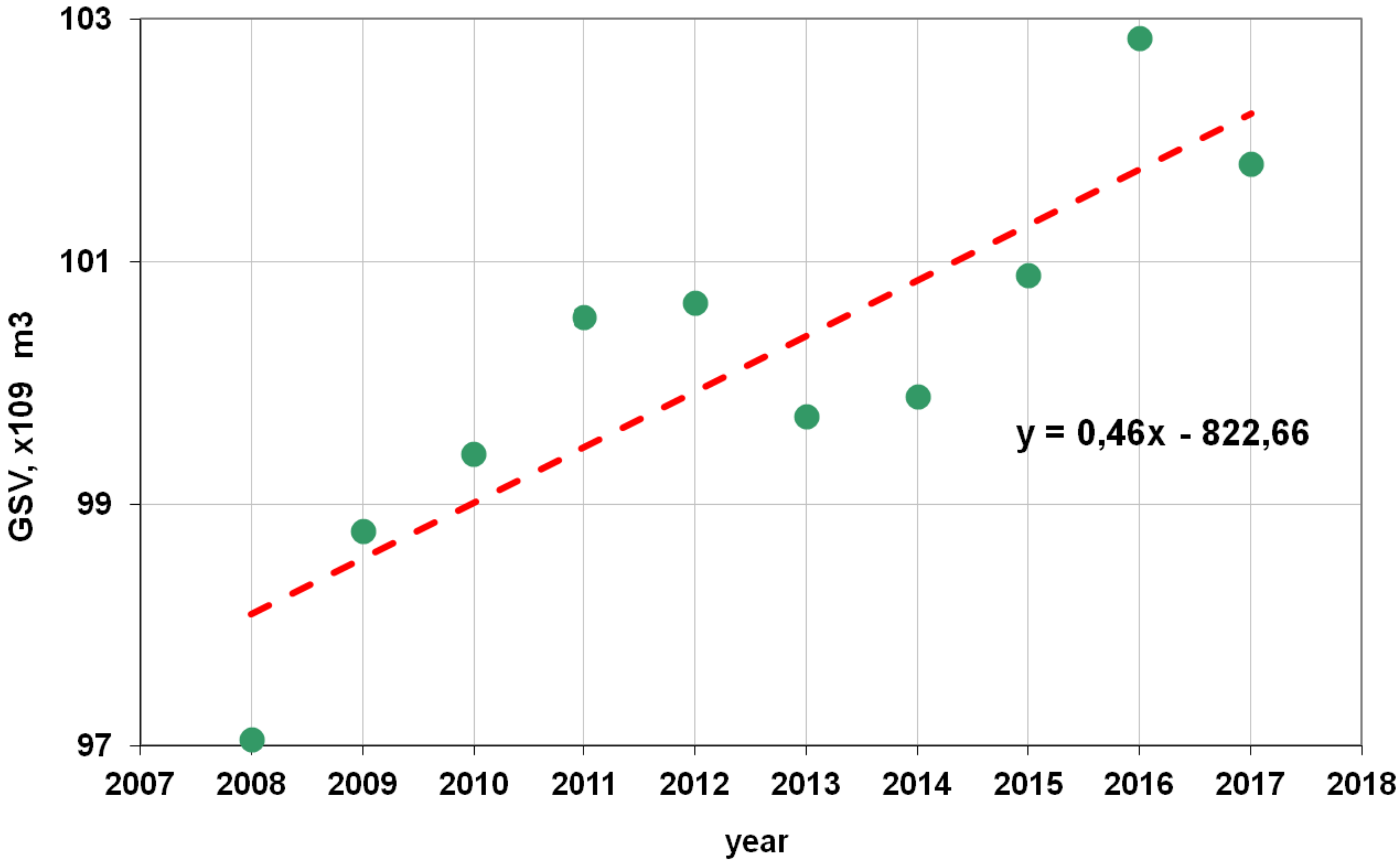
	Official Statistics	RS lower estimate	RS upper estimate
GSV $x10^9$ m^3	82,8	101,8	104,7
Forest Area x 10^6 ha	796,9	754,1	784,2
Relative GSV m^3/ha	103,9	135,0	133,5

Russian forest area change



FACR – annual forest area change (ha x year^{-1})

Growing Stock Volume Dynamics in Russian Forest based on Remote Sensing Data



Барталев С.А., Егоров В.А., Жарко В.О., Лупян Е.А., Плотников Д.Е., Хвостиков С.А., Шабанов Н.В. Спутниковое картографирование растительного покрова России // М.: ИКИ РАН, 2016. 208 с.

При поддержке Российского научного фонда (грант № 14-17-00389).

Проект «Космическая научная обсерватория углерода лесов России»

Грант Российского Научного Фонда (№ 19-77-30015) для проведения исследований на базе Лаборатории мирового уровня на тему «Разработка методов и технологии комплексного использования данных дистанционного зондирования Земли из космоса для развития системы национального мониторинга бюджета углерода лесов России в условиях глобальных изменений климата»

Период реализации Проекта: 2019-2022 годы, с возможным продолжением до 2025 года

Вакансии: открыто 3 вакансии для включения в состав научного коллектива Проекта молодых ученых (до 35 лет) с ученой степенью

Заявления направлять **до 31 декабря 2019 года руководителю Проекта Барталеву С.А.** (E-mail: bartalev@d902.iki.rssi.ru)

Thank you for your attention !

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