



Russian Academy of Sciences  
Space Research Institute

**Monitoring of vegetation dynamics in  
Northern Eurasia using time-series of  
moderate resolution satellite data :  
R&D status review**

**Bartalev Sergey and Ershov Dmitry**

**with acknowledged contribution from**

**Egorov V., Khovratovich T., Loupian E.,**

**Neyshadt I., Uvarov I.**

# Earth Observation Instruments for Terrestrial Ecosystems Monitoring

Thematic focuses of consideration



Earth Observation tasks	Satellite instruments of different spatial resolution			
	Low (~ 1000 m)	Medium (250-500 m)	High (20-50 m)	Detailed (1-5 m)
<b>Land cover mapping</b>	NOAA-AVHRR SPOT-Vegetation Terra/Aqua-MODIS	Terra/Aqua-MODIS Envisat-MERIS	Landsat-ETM+ Terra-ASTER SPOT-HRVIR Meisop/MCY-3 IRS-LISS	IKONOS Quick-Bird SPOT-HRG IRS-PAN
<b>Biophysical and biochemical properties assessment</b>				
<i>Green biomass, LAI, NPP, fPAR</i>				
<i>Chlorophyll content</i>		Envisat-MERIS		
<i>3D vegetation structure</i>	SPOT-Vegetation	Terra-MISR Terra/Aqua-MODIS		
<b>Disturbances assessment</b>				
<i>Active fires</i>	NOAA-AVHRR Terra/Aqua-MODIS		Landsat-ETM+ Terra-ASTER	
<b>Burnt area</b>	NOAA-AVHRR SPOT-Vegetation Terra/Aqua-MODIS	Terra/Aqua-MODIS	Landsat-ETM+ Terra-ASTER SPOT-HRVIR Meisop/MCY-3 IRS-LISS	IKONOS Quick-Bird SPOT-HRG IRS-PAN
<i>Biotic disturbance factors</i>				
<i>Industrial pollutions</i>				
<i>Forest logging</i>				
<b>Land-Use assessment</b>				
<b>Phenological rhythms assessment</b>	NOAA-AVHRR SPOT-Vegetation Terra/Aqua-MODIS			
<b>Long-term trends assessments</b>			Landsat-ETM+ SPOT-HRVIR	
<b>Physical properties assessment</b>	NOAA-AVHRR Terra/Aqua-MODIS		Landsat-ETM+ Terra-ASTER	

# **SPOT-VEGETATION and MODIS data preprocessing**



# VEGETATION and MODIS data archive for N. Eurasia

## **SPOT-VEGETATION :**

### ***Maximum NDVI ten-day composites***

(S10 product)

**Geographical coverage:** 42°-75°N  
5°-180°E

**Time frame:** 1998 – ongoing

**Temporal resolution:** 10 days

### **Spectral bands:**

i. 430 – 470 nm

ii. 610 – 680 nm

iii. 780 – 890 nm

iv. 1580 – 1750 nm

**Spatial resolution:** 1.15km (nadir view)

**Data delivery:** Internet access with 3  
months delay (<http://free.vgt.vito.be>)

## **Terra-MODIS :**

### ***Surface Reflectance Product***

(MOD09GHK, MOD09GQK, MODMGGAD, MOD09GST)

**Geographical coverage:** entire N.Eurasia  
(in process, ~70% completeness)

**Time frame:** 2002 – ongoing

**Temporal resolution:** daily

### **Main spectral bands used:**

i. 440 – 480 nm

ii. 620 – 670 nm

iii. 841 – 976 nm

iv. 1630 – 1650 nm

**Spatial resolution:** 250&500m (nadir view)

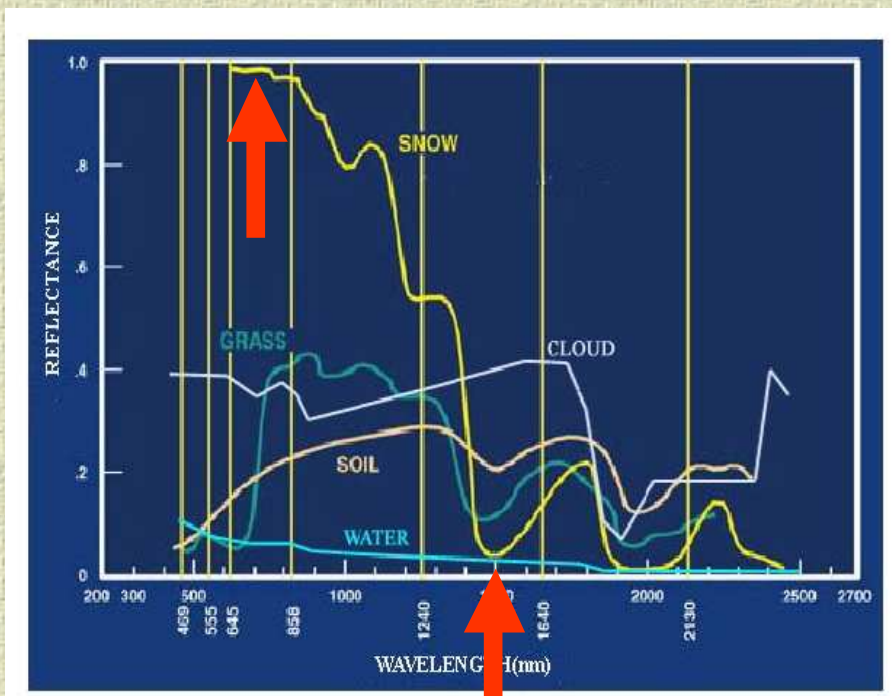
**Data delivery:** Internet access with 2-7  
days delay (<http://modis.gsfc.nasa.gov>)

# VEGETATION and MODIS data pre-processing steps

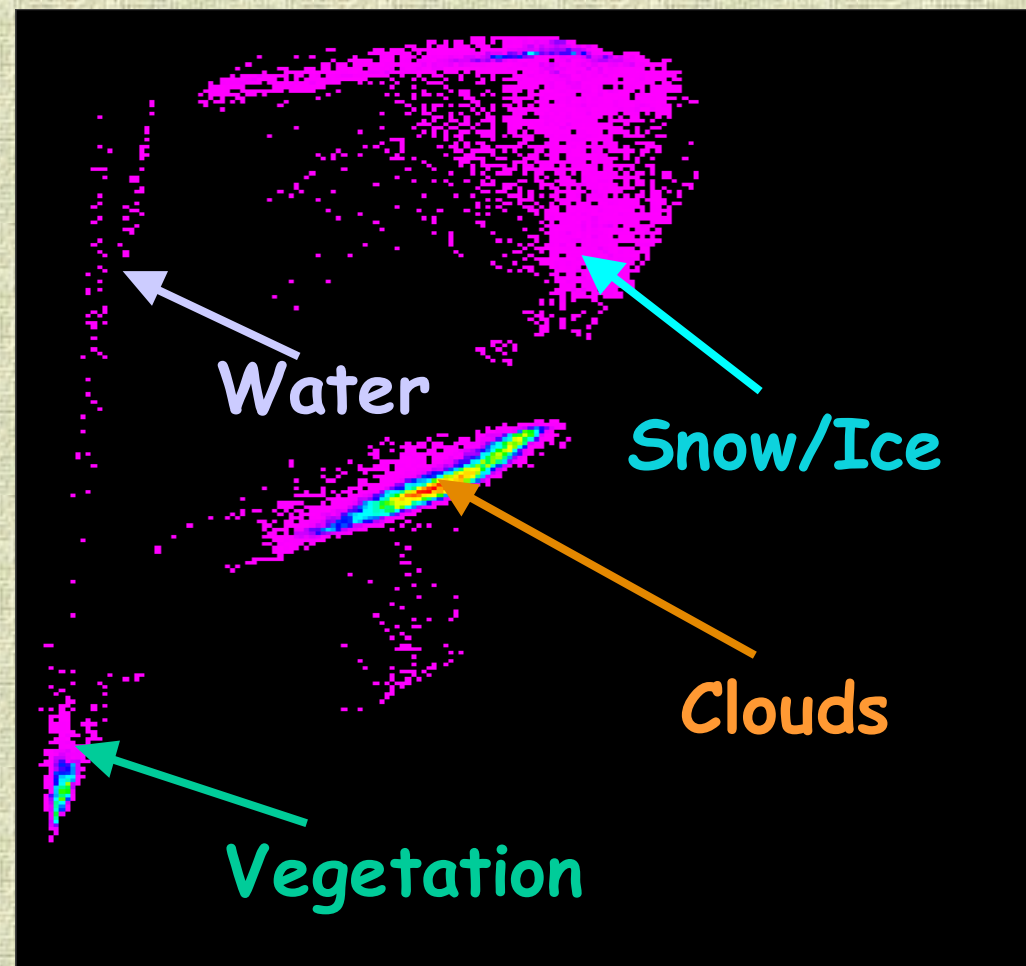
Data pre-processing steps	Method	Satellite Instrument	
		VGT	MODIS
Cloud / snow screening	– Fixed thresholding using spectral channels and indexes	+	+
Shadow detection	– Geometrical modelling – Spatial-temporal analysis	-	+
Spatial resolution selection	– Fixed thresholding using the pixel size data	-	+
Random noise filtering	– Statistically adjusted thresholding using spectral reflectance temporal profiles for “snow/cloud free” pixels	+	+
Permanent snow mapping	– Statistically adjusted thresholding using spectral reflectance temporal profiles for “snow covered” pixels	+	+
Temporal compositing	– Minimum distance from temporal average of uncontaminated pixels	+	+



# Snow and Cloud Discrimination



NDSI

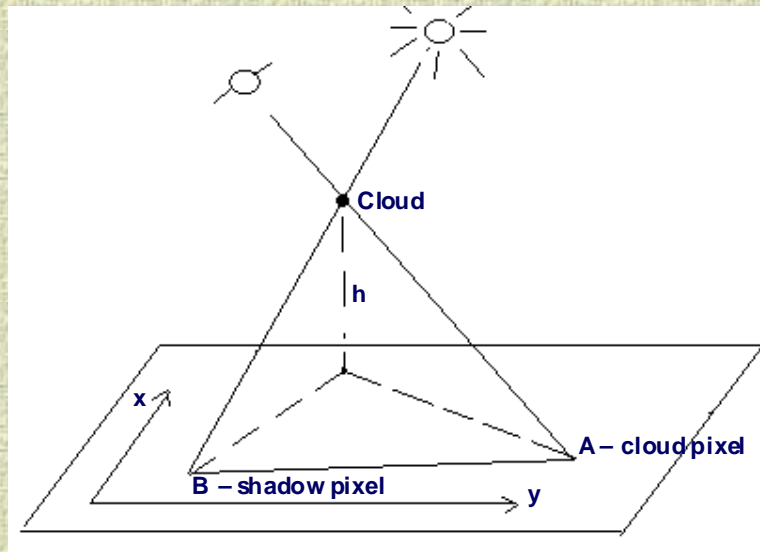


$$NDSI = \frac{R_{blu} - R_{swir}}{R_{blu} + R_{swir}}$$

Red channel

# Clouds' Shadow Detection

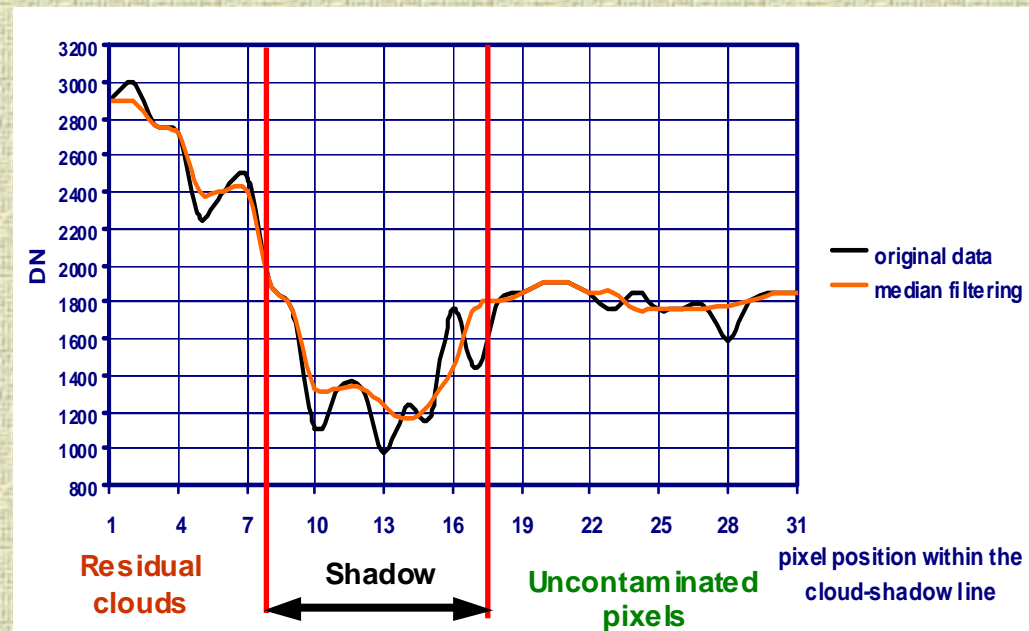
## Step 1. Geometrical modelling of the cloud-shadow line



$$\overline{AB} = h \begin{pmatrix} \cos \psi \tan \theta - \cos \beta \tan \delta \\ \sin \psi \tan \theta - \sin \beta \tan \delta \end{pmatrix}$$

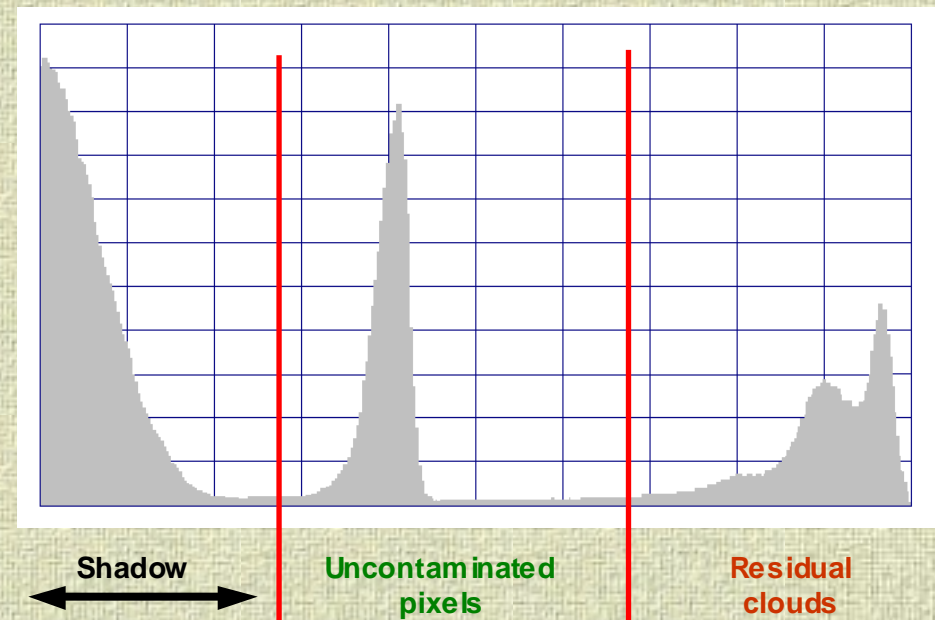
- $\psi$  - view azimuth angle
- $\theta$  - view zenith angle
- $\beta$  - solar azimuth angle
- $\delta$  - solar zenith angle

## Step 2. Shadow detection along cloud-shadow line



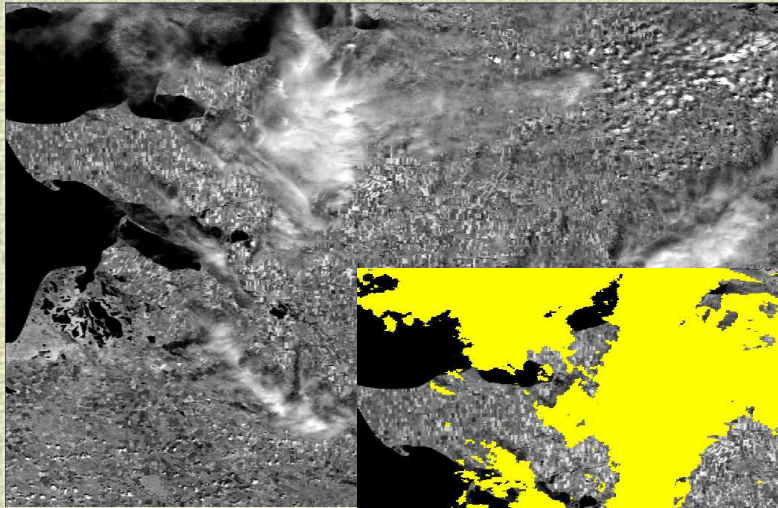
## Step 3. Shadow detection along temporal profile

### Histogram Analysis

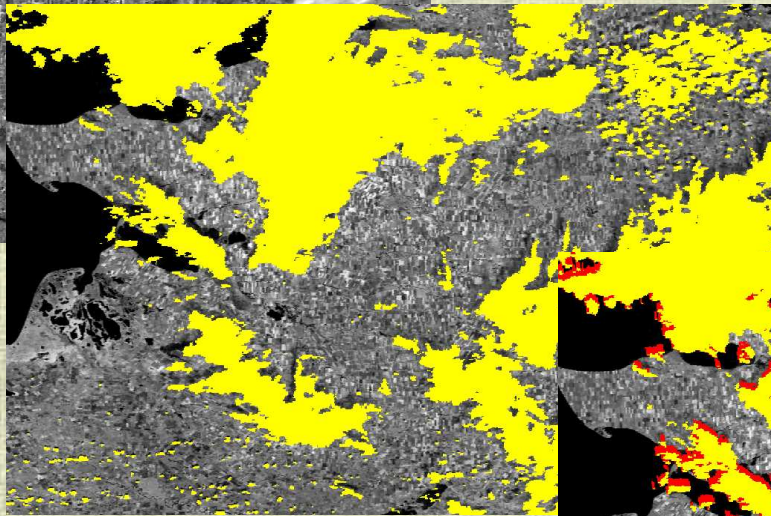




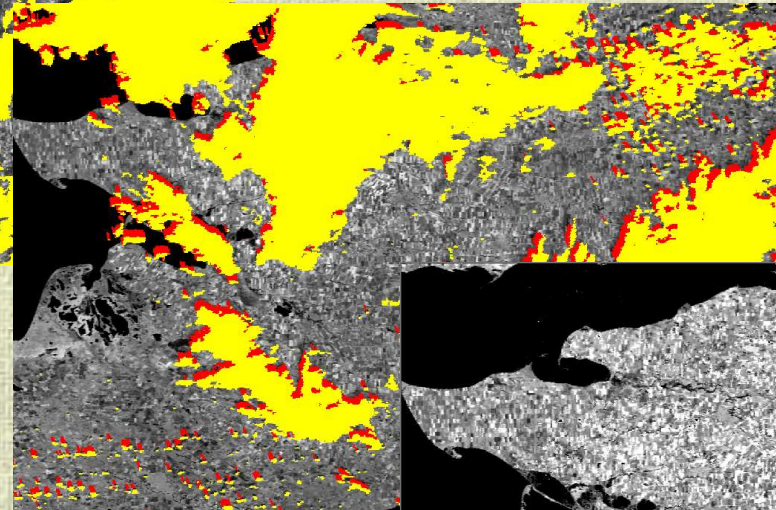
# MODIS data pre-processing steps



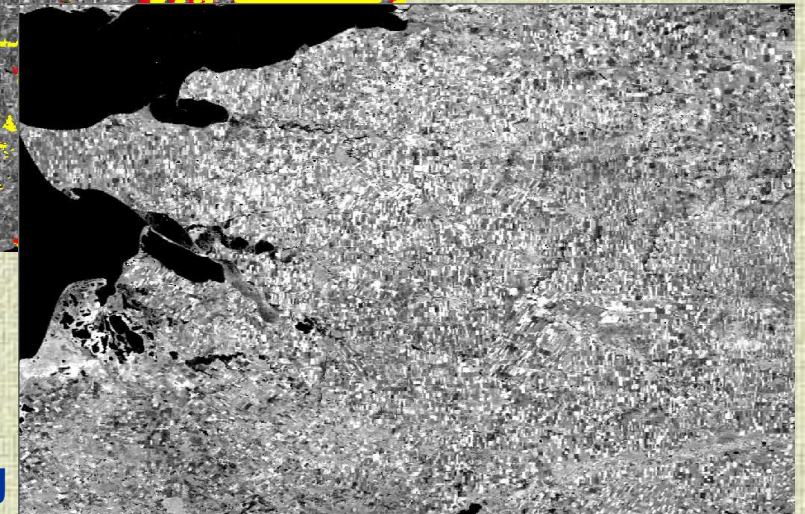
MODIS daily products



Snow/cloud detection



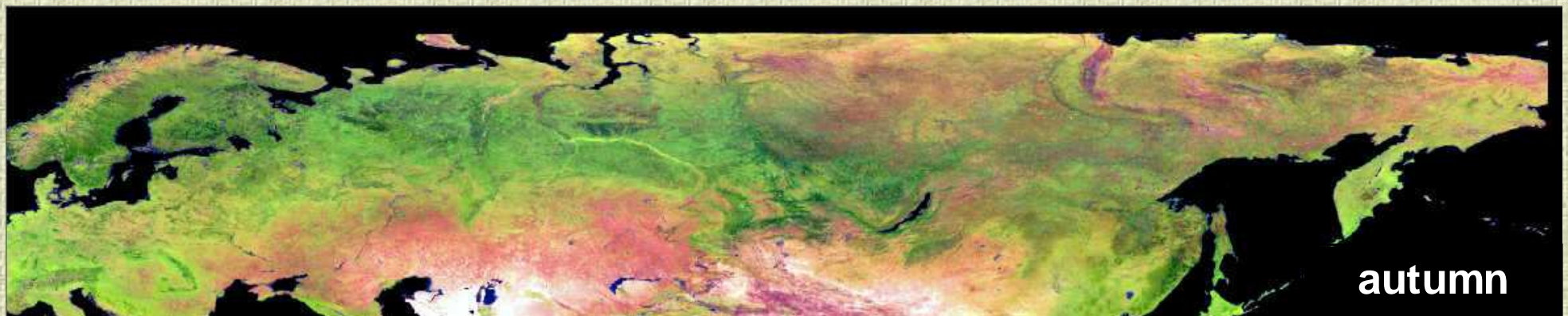
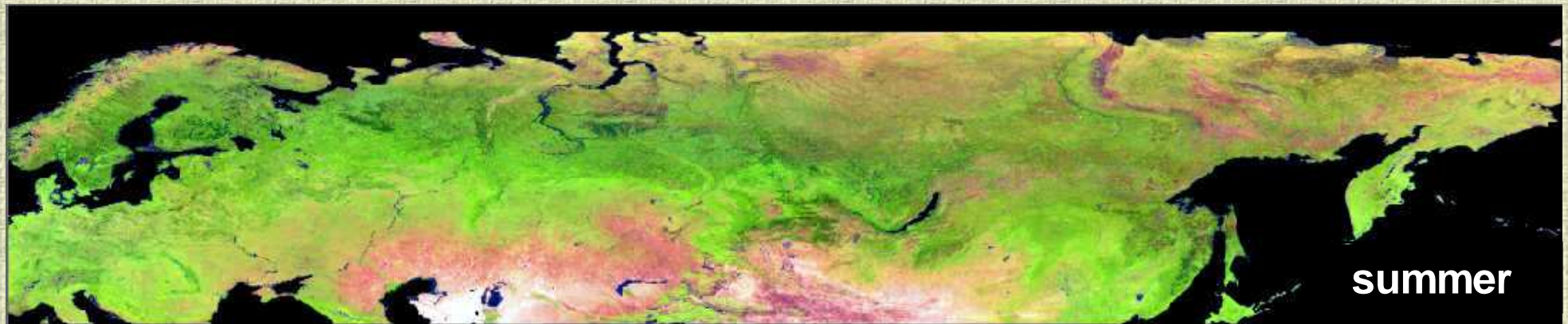
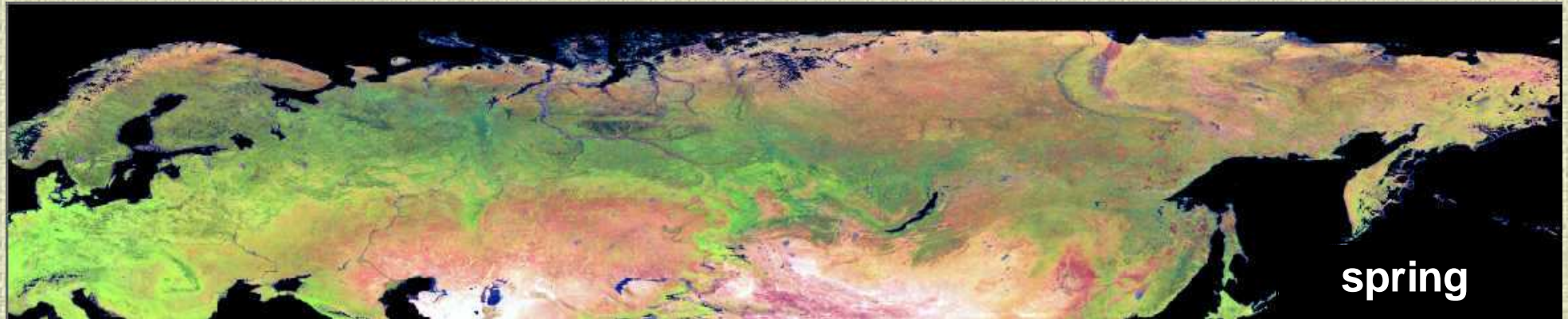
Cloud shadow detection



Temporal compositing

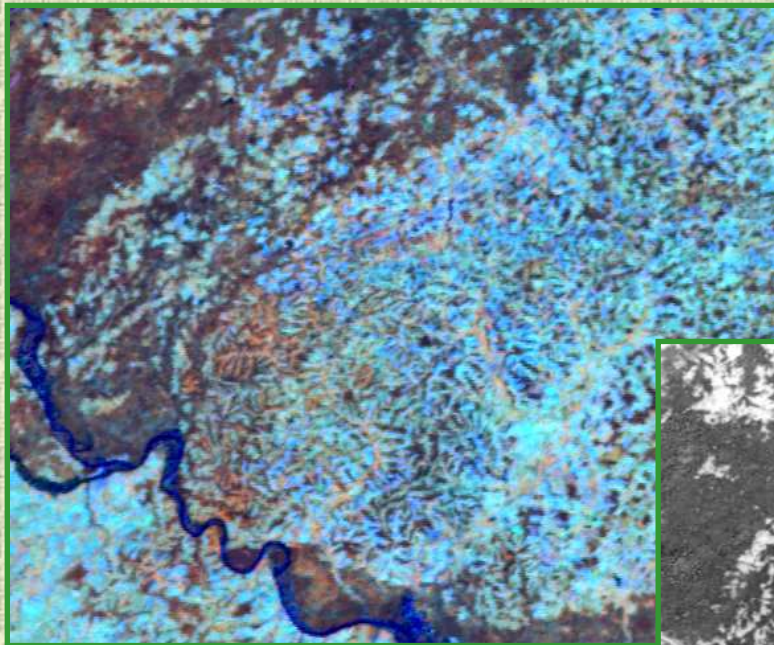


# The seasonal mosaics for N.Eurasia from S10 SPOT-VGT data

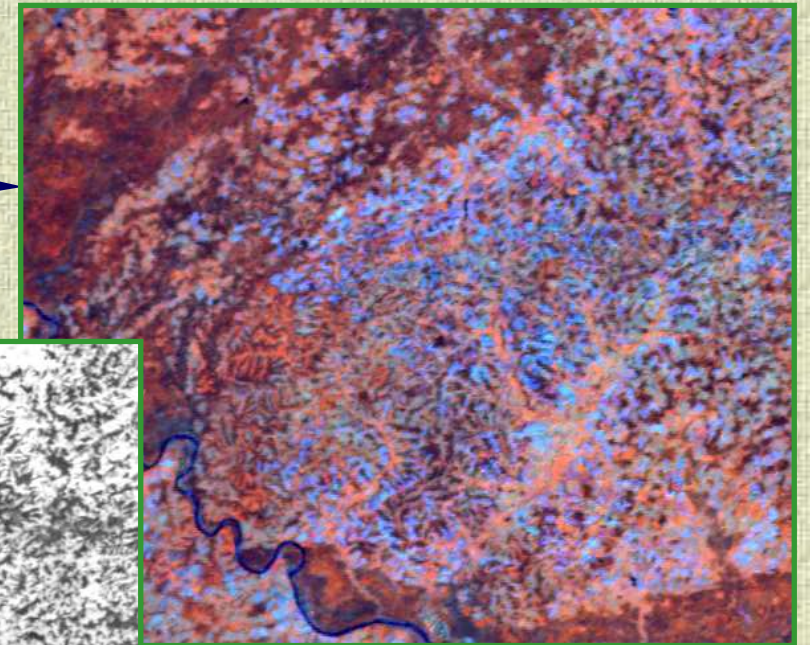




# MODIS Mosaics Examples

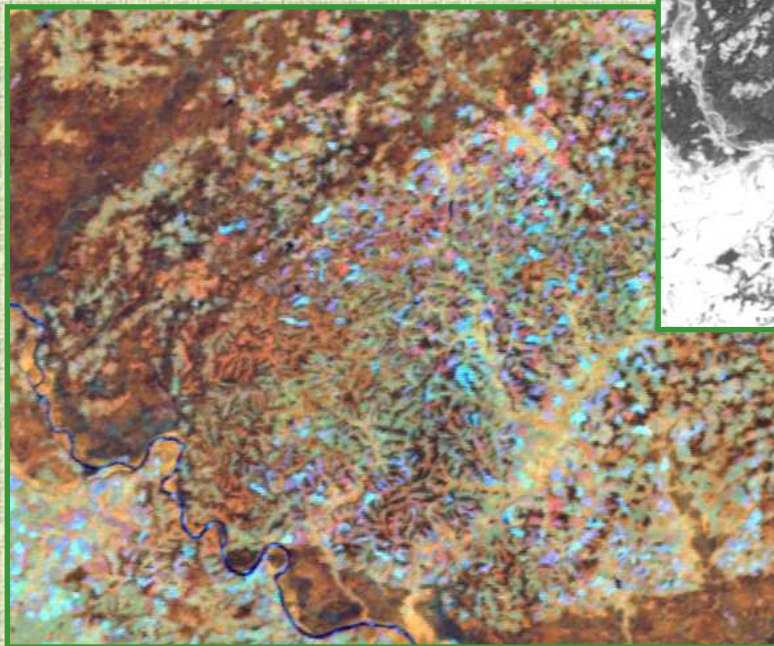
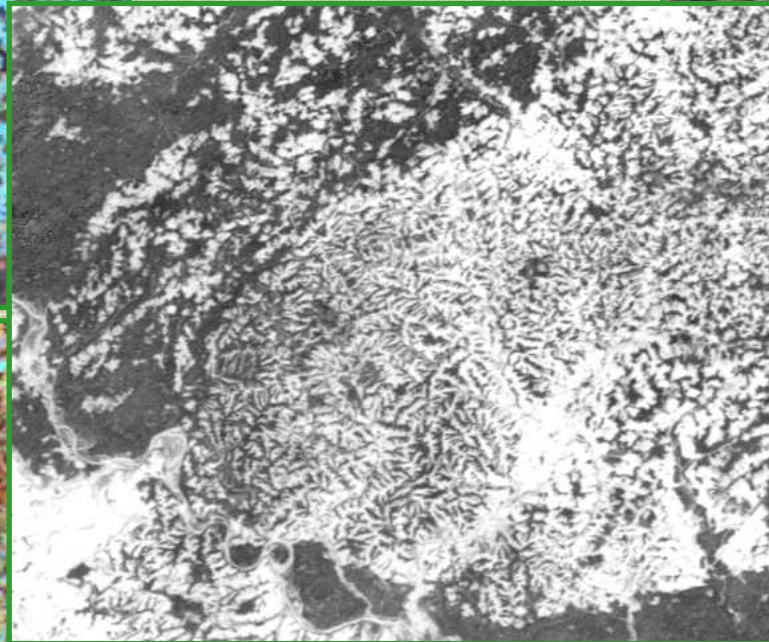


← May

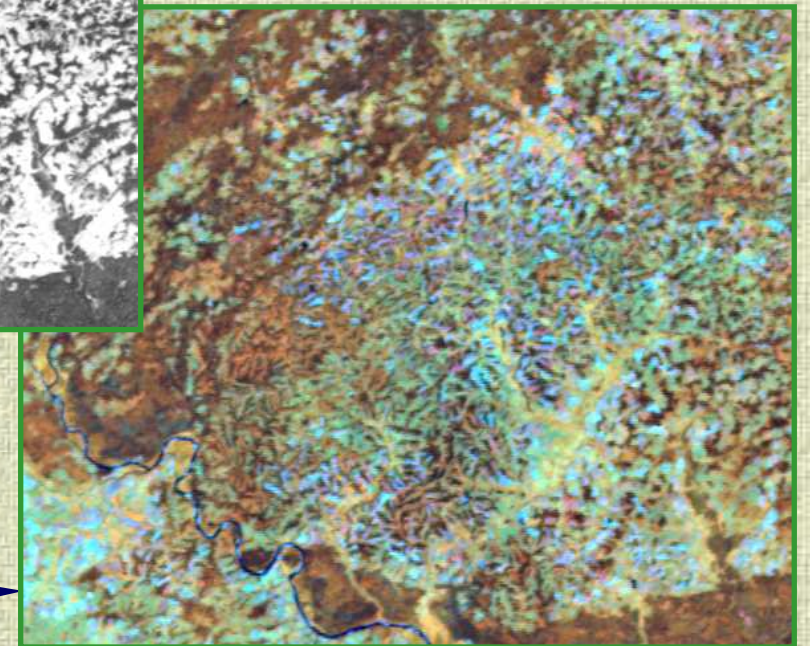


June →

Winter



← July



August →



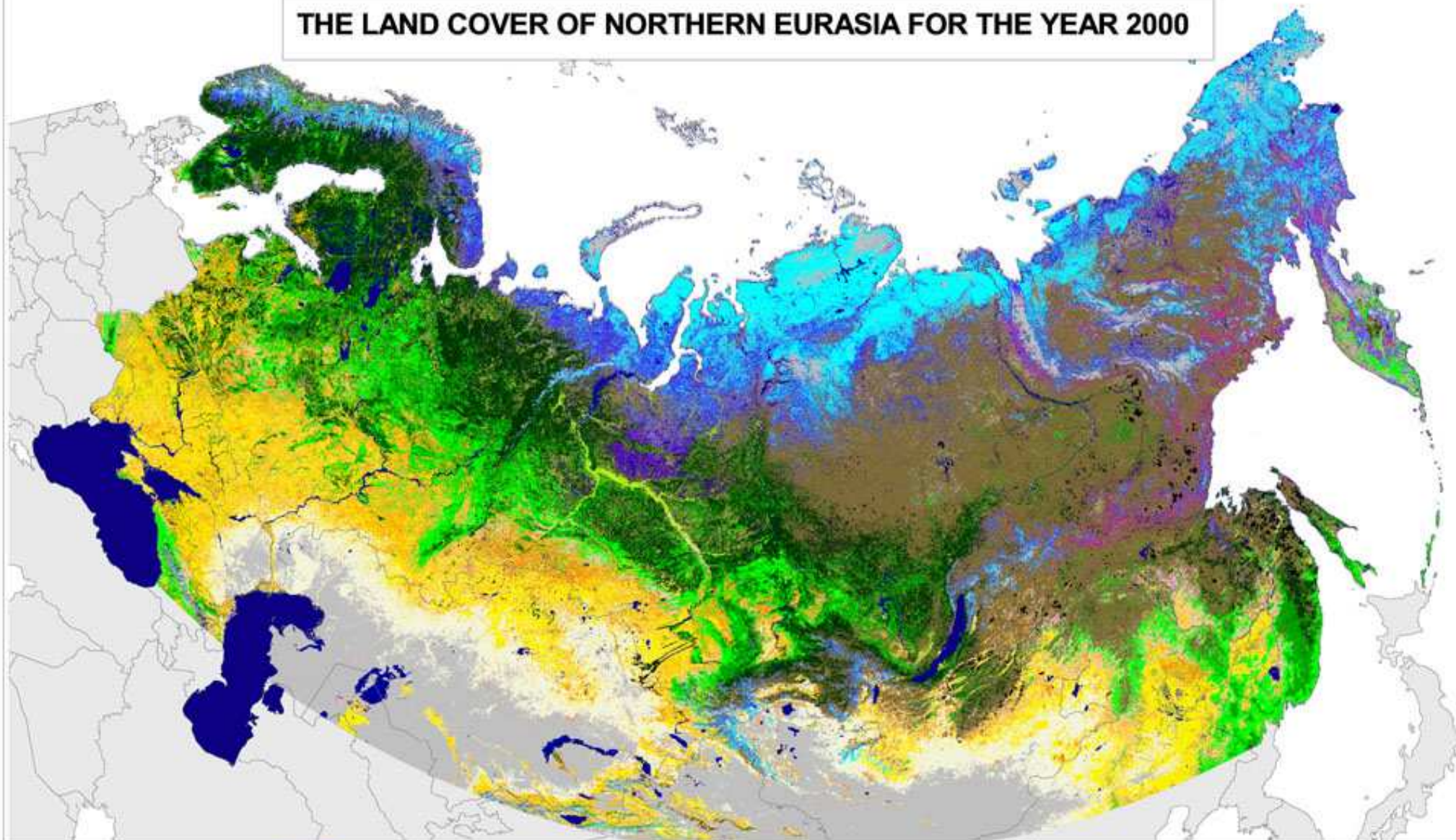
# Land Cover Mapping



S.Vasiliev <sv@issa.nsc.ru>



# THE LAND COVER OF NORTHERN EURASIA FOR THE YEAR 2000



**LEGEND / РЕГИОНА**

<p><b>FORESTS / ЛЕСА</b></p> <ul style="list-style-type: none"> <li><span style="color: green;">■</span> European Broadleaf Forest</li> <li><span style="color: darkgreen;">■</span> European Broadleaf Forest</li> <li><span style="color: forestgreen;">■</span> European Broadleaf Forest</li> <li><span style="color: darkgreen;">■</span> European Broadleaf Forest</li> <li><span style="color: forestgreen;">■</span> European Broadleaf Forest</li> <li><span style="color: darkgreen;">■</span> European Broadleaf Forest</li> <li><span style="color: forestgreen;">■</span> European Broadleaf Forest</li> <li><span style="color: darkgreen;">■</span> European Broadleaf Forest</li> </ul>	<p><b>WATER BODIES / ВОДНЫЕ ТЕЛА</b></p> <ul style="list-style-type: none"> <li><span style="color: blue;">■</span> Broadleaf European Broad</li> <li><span style="color: darkblue;">■</span> Broadleaf European Broad</li> <li><span style="color: lightblue;">■</span> Broadleaf European Broad</li> <li><span style="color: cyan;">■</span> Broadleaf European Broad</li> <li><span style="color: lightblue;">■</span> Broadleaf European Broad</li> <li><span style="color: cyan;">■</span> Broadleaf European Broad</li> <li><span style="color: lightblue;">■</span> Broadleaf European Broad</li> <li><span style="color: cyan;">■</span> Broadleaf European Broad</li> </ul>	<p><b>AGRICULTURE / СЕЛЬСКОХОЗЯЙСТВЕННАЯ ТЕРРИТОРИЯ</b></p> <ul style="list-style-type: none"> <li><span style="color: yellow;">■</span> Broadleaf European Broad</li> <li><span style="color: orange;">■</span> Broadleaf European Broad</li> <li><span style="color: lightyellow;">■</span> Broadleaf European Broad</li> <li><span style="color: yellowgreen;">■</span> Broadleaf European Broad</li> <li><span style="color: lightyellowgreen;">■</span> Broadleaf European Broad</li> <li><span style="color: yellowgreen;">■</span> Broadleaf European Broad</li> <li><span style="color: lightyellowgreen;">■</span> Broadleaf European Broad</li> <li><span style="color: yellowgreen;">■</span> Broadleaf European Broad</li> </ul>	<p><b>OTHER VEGETATION TYPES AND COMPLEXES / ДРУГИЕ ВИДЫ РАСТИТЕЛЬНОСТИ И КОМПЛЕКСЫ</b></p> <ul style="list-style-type: none"> <li><span style="color: brown;">■</span> Broadleaf European Broad</li> <li><span style="color: tan;">■</span> Broadleaf European Broad</li> <li><span style="color: lightbrown;">■</span> Broadleaf European Broad</li> <li><span style="color: tan;">■</span> Broadleaf European Broad</li> <li><span style="color: lightbrown;">■</span> Broadleaf European Broad</li> <li><span style="color: tan;">■</span> Broadleaf European Broad</li> <li><span style="color: lightbrown;">■</span> Broadleaf European Broad</li> <li><span style="color: tan;">■</span> Broadleaf European Broad</li> </ul>	<p><b>NON-VEGETATED LAND COVER TYPES / НЕРАСТИТЕЛЬНЫЕ ВИДЫ ПОКРЫТИЯ ПОверхНОСТИ</b></p> <ul style="list-style-type: none"> <li><span style="color: grey;">■</span> Broadleaf European Broad</li> <li><span style="color: lightgrey;">■</span> Broadleaf European Broad</li> <li><span style="color: white;">■</span> Broadleaf European Broad</li> <li><span style="color: lightgrey;">■</span> Broadleaf European Broad</li> <li><span style="color: white;">■</span> Broadleaf European Broad</li> <li><span style="color: lightgrey;">■</span> Broadleaf European Broad</li> <li><span style="color: white;">■</span> Broadleaf European Broad</li> <li><span style="color: lightgrey;">■</span> Broadleaf European Broad</li> </ul>
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**MAP INFORMATION**

Scale: 0 200 400 km

Map projection: Projection: Albers Equal-Area Conic, Spheroid: WGS84, Central Meridian: 87° E, Reference latitude: 57° N, Standard Parallel 1: 50° N, Standard Parallel 2: 50° N

This map of Northern Eurasia's land cover has been created at European Commission's Joint Research Centre in partnership with Russian Academy of Sciences' Centre for Forest Ecology and Productivity. The mapping has been performed as part of Global Land Cover 2000 project with use of data obtained by the VEGETATION sensor on board the Earth Observation satellite SPOT-4. Land cover classes have been identified with series of advanced data products, derived from VEGETATION data. In order to characterize phenology of vegetation, water content of surface, directional reflectance properties and snow duration.

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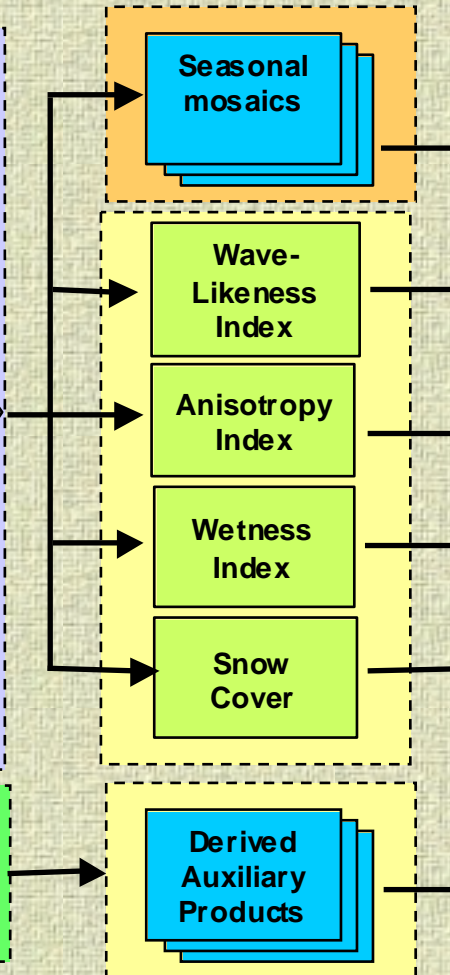
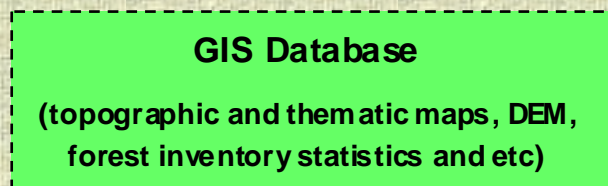
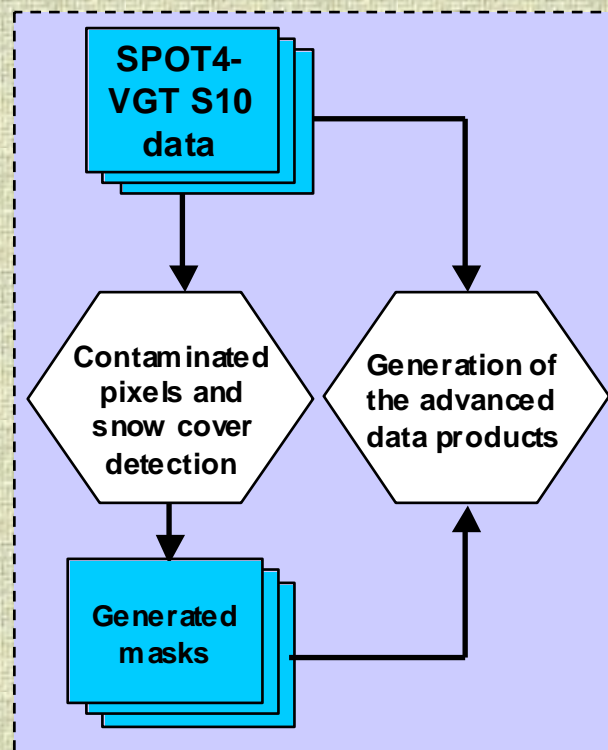
**Russian Academy of Sciences**

**EUROPEAN COMMISSION**

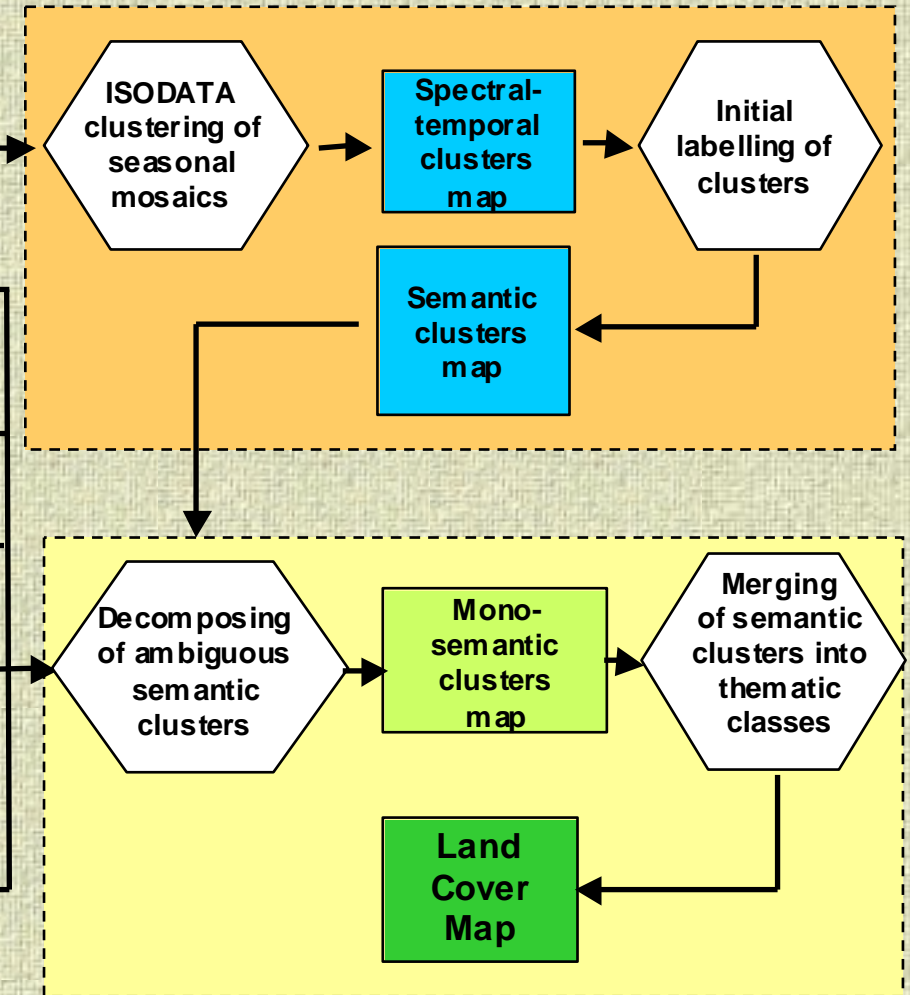


# Land Cover Mapping Method

## Image pre-processing and generation of advanced data products

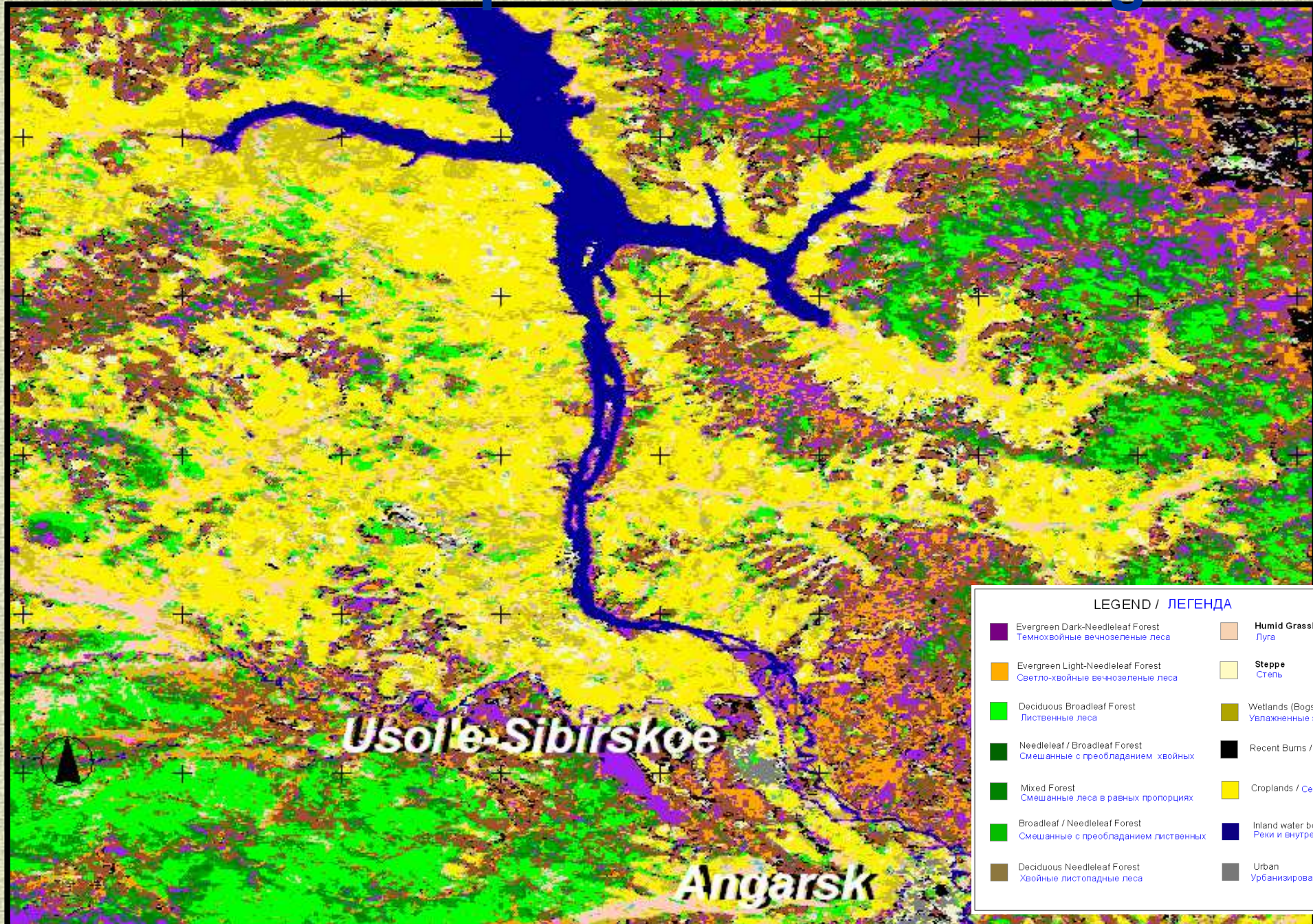
















## Image classification





# VEGETATION (GLC 2000) and MODIS land cover maps for Lake Baikal region



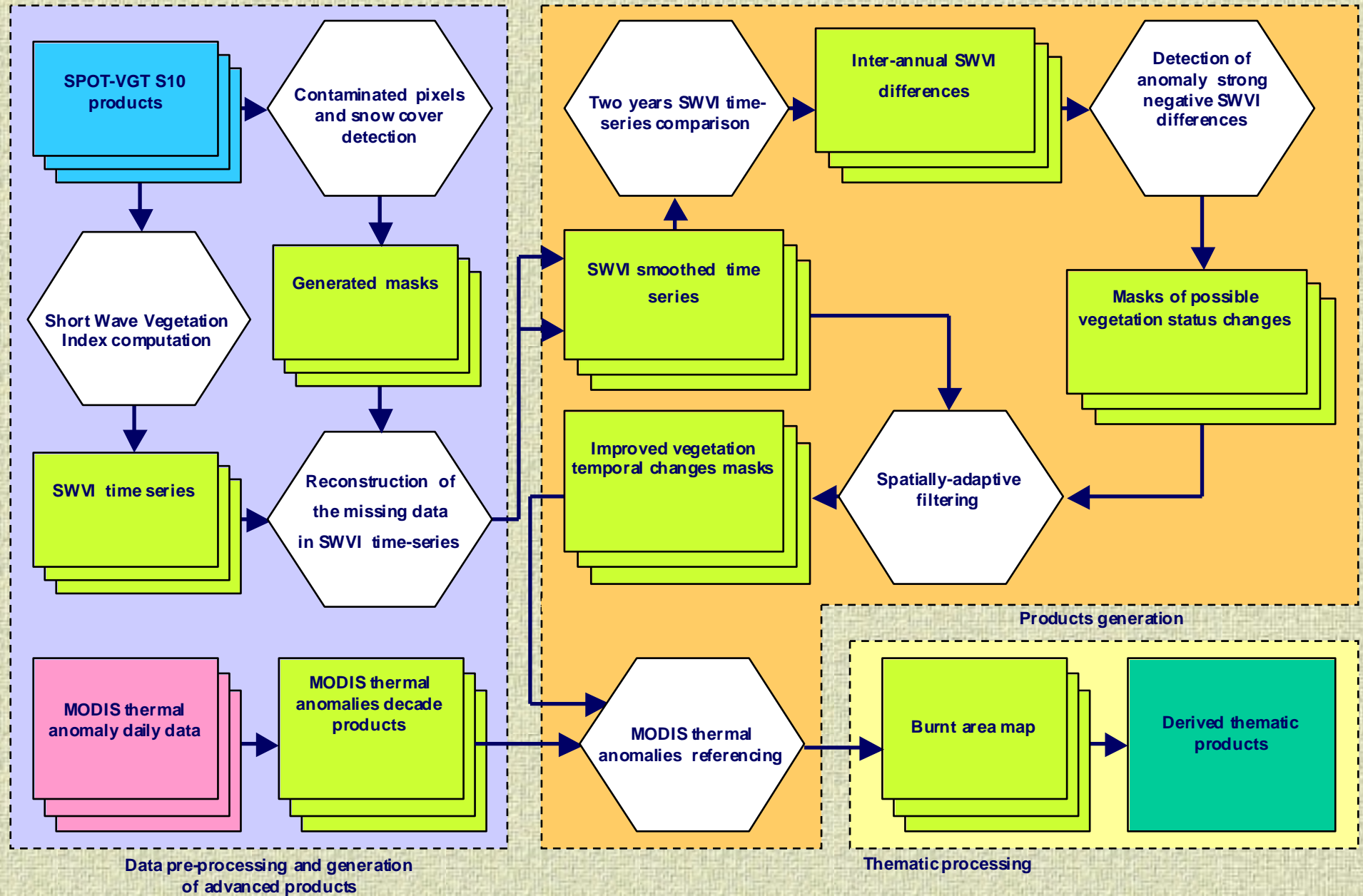
LEGEND / ЛЕГЕНДА	
 Evergreen Dark-Needleleaf Forest Темнохвойные вечнозеленые леса	 Humid Grasslands Луга
 Evergreen Light-Needleleaf Forest Светло-хвойные вечнозеленые леса	 Steppe Степь
 Deciduous Broadleaf Forest Лиственные леса	 Wetlands (Bogs and Marsh) Увлажненные земли (болота)
 Needleleaf / Broadleaf Forest Смешанные с преобладанием хвойных	 Recent Burns / Свежие лесные гари
 Mixed Forest Смешанные леса в равных пропорциях	 Croplands / Сельскохозяйственные земли
 Broadleaf / Needleleaf Forest Смешанные с преобладанием лиственных	 Inland water bodies Реки и внутренние водоемы
 Deciduous Needleleaf Forest Хвойные листопадные леса	 Urban Урбанизированные территории



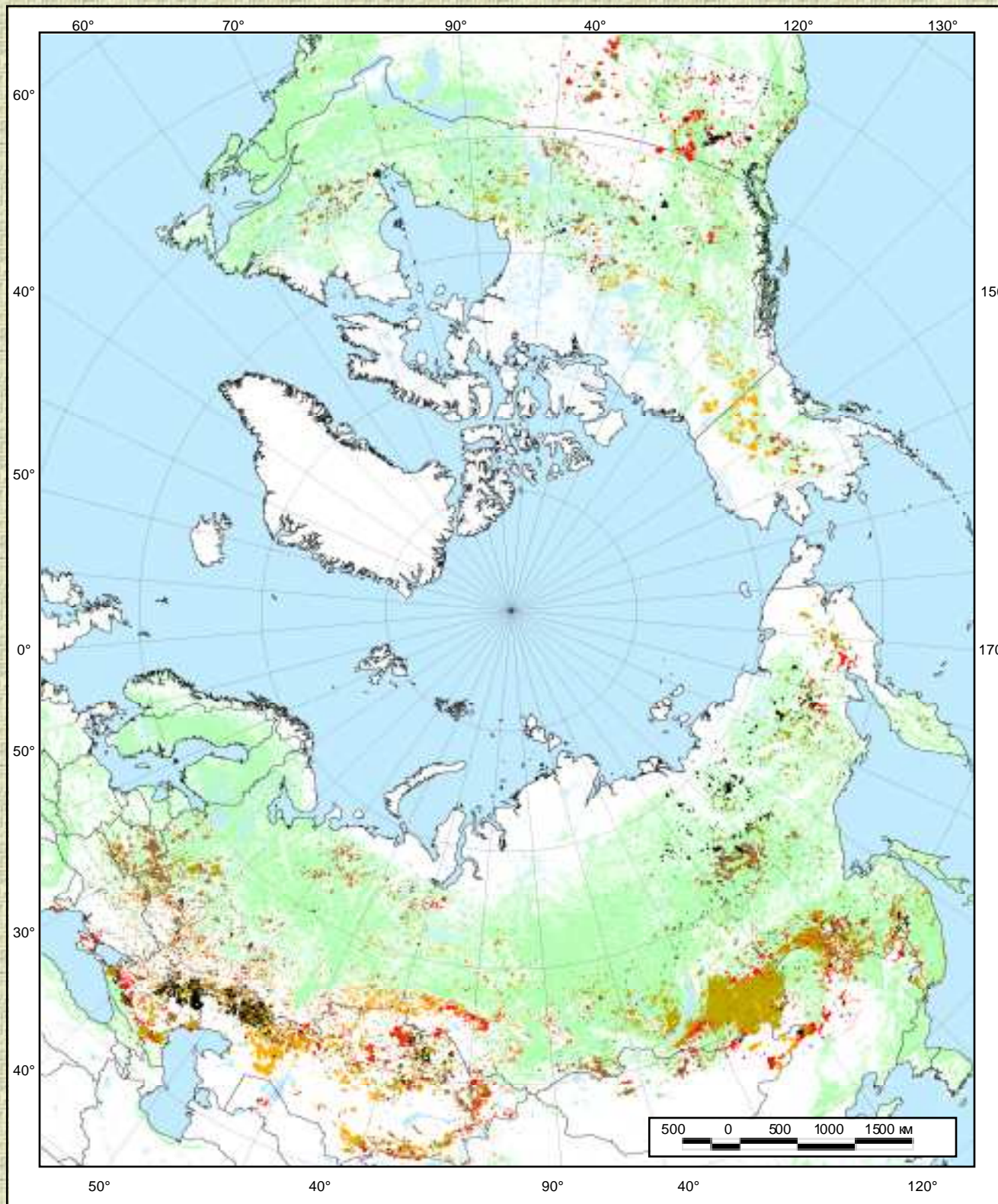
# Fire Impact Assessment



# Burnt area mapping method using VEGETATION time-series data



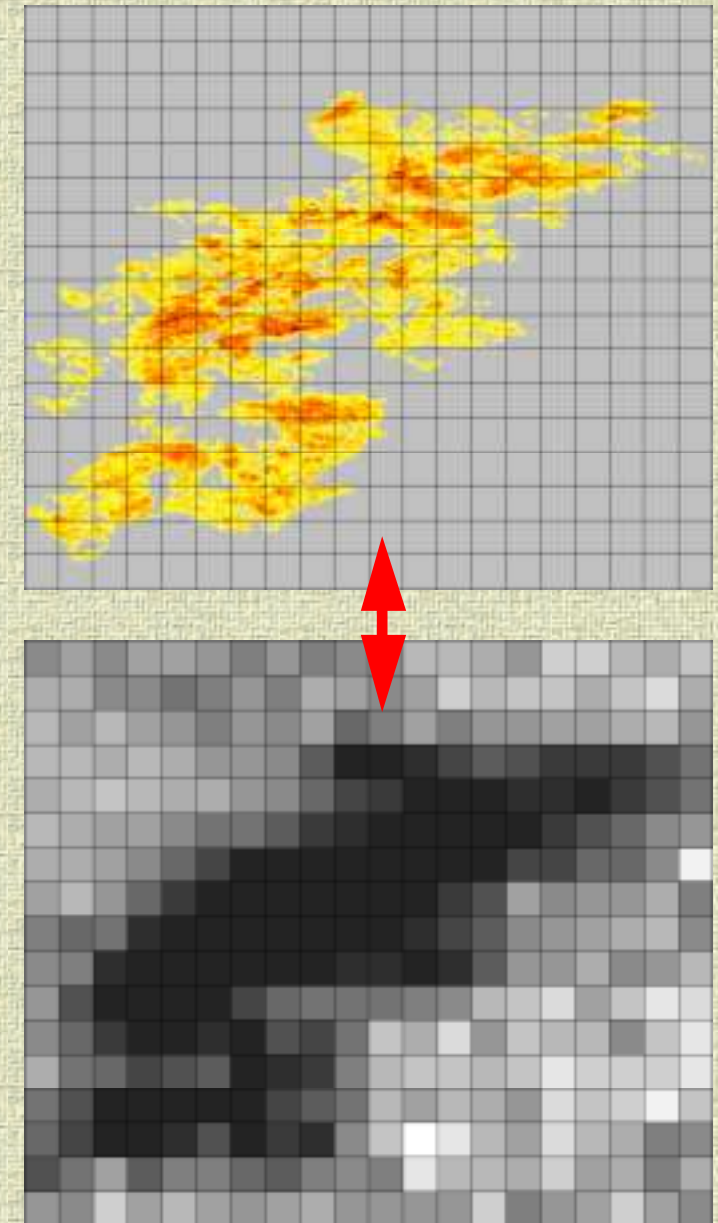
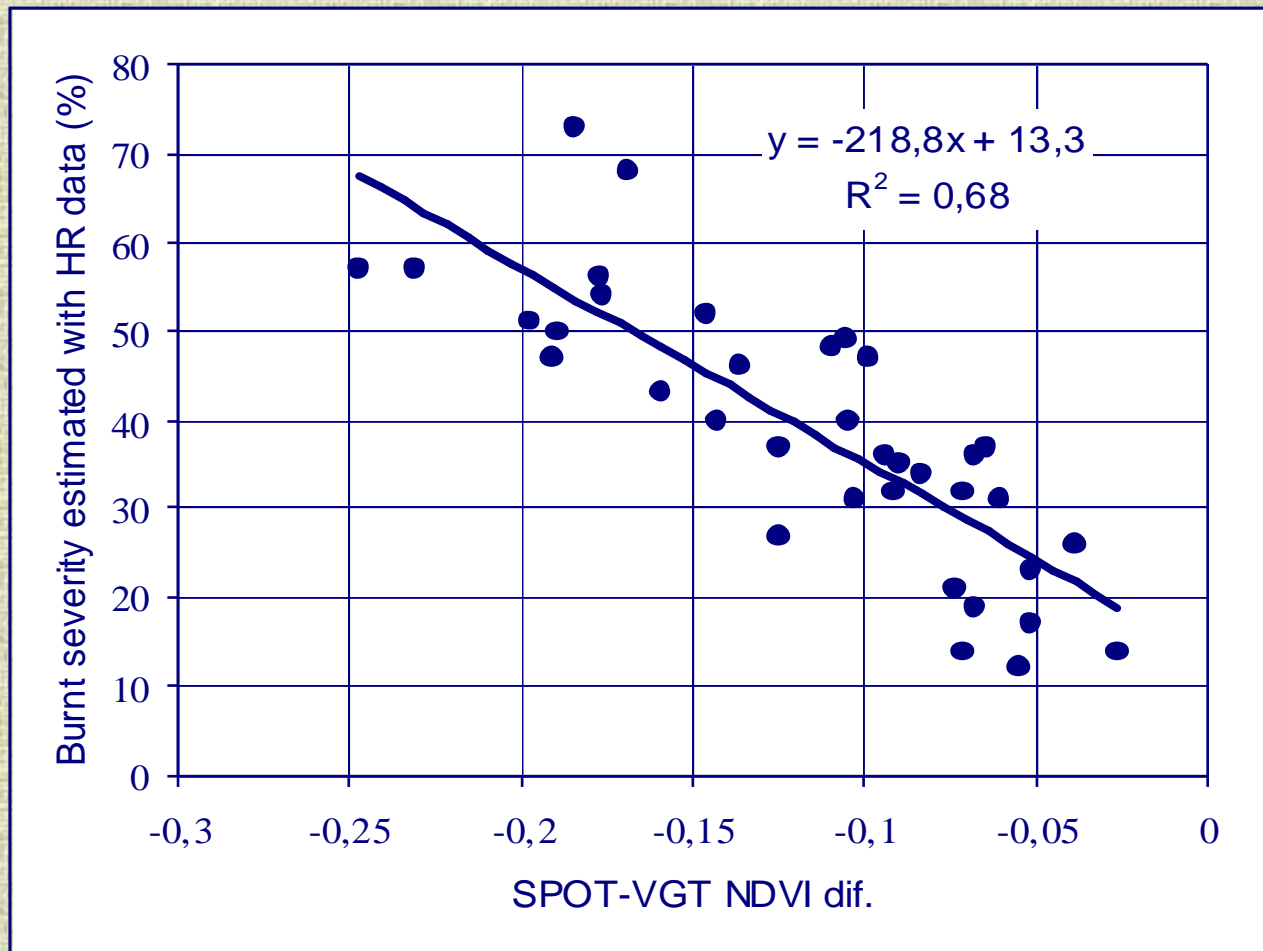




## SPOT-Vegetation data derived Circumpolar burnt area for 2000-2004

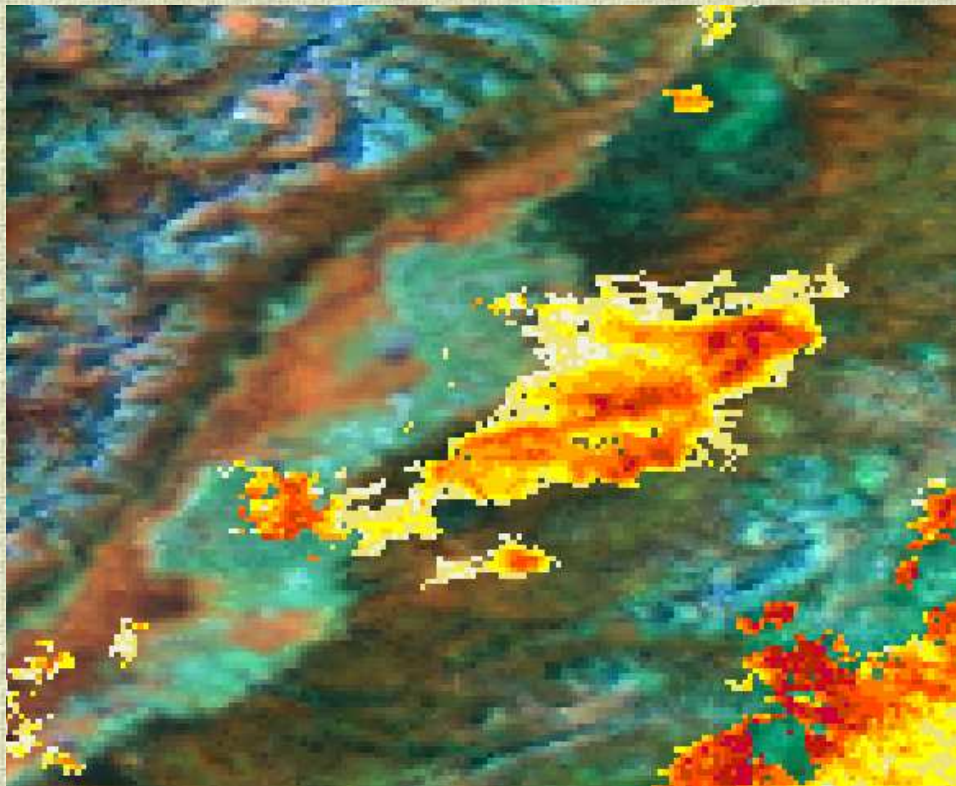


# Burn severity assessment using VEGETATION and high-resolution sampling data

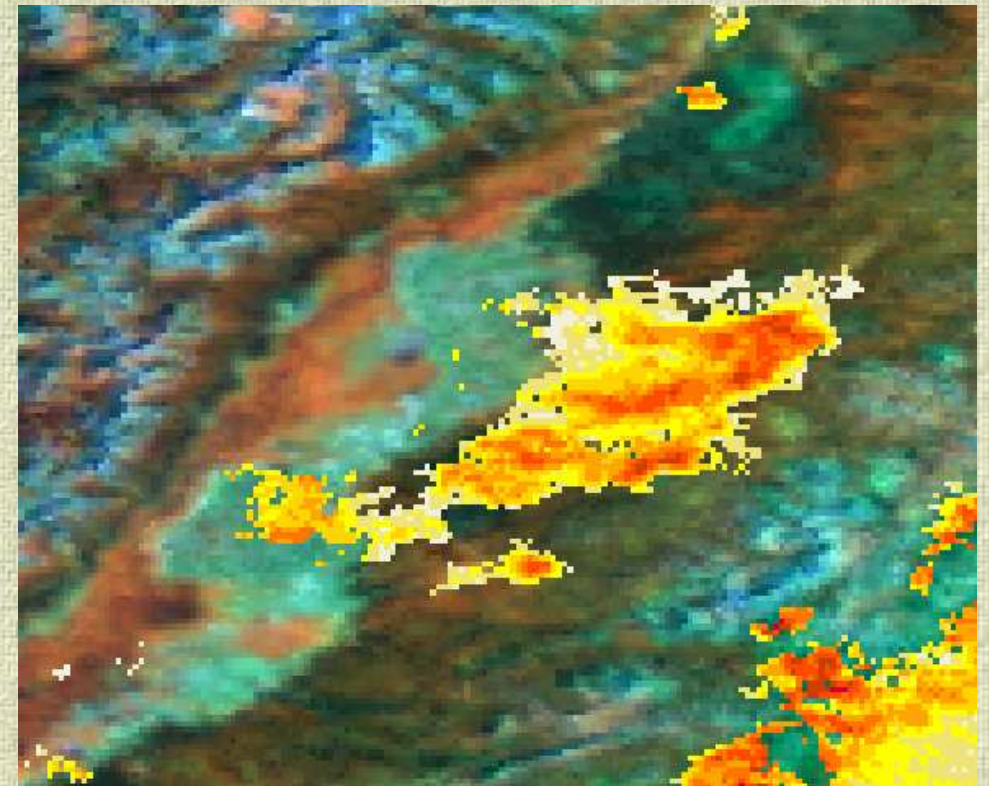




# Comparison of forest burn severity assessment from VEGETATION using two different methods



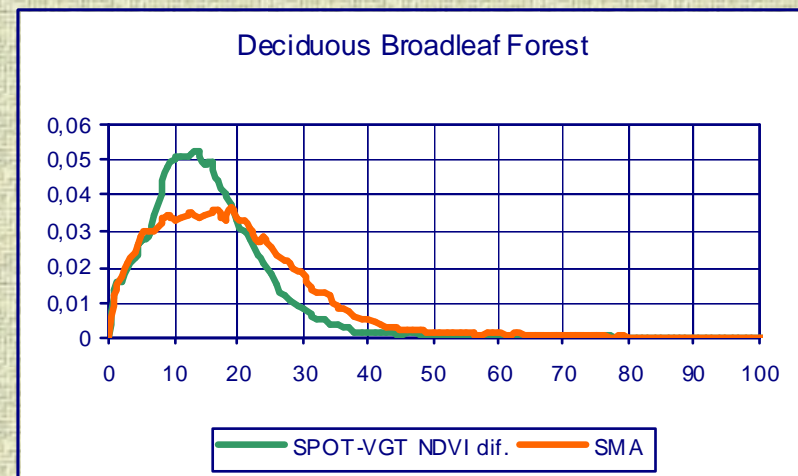
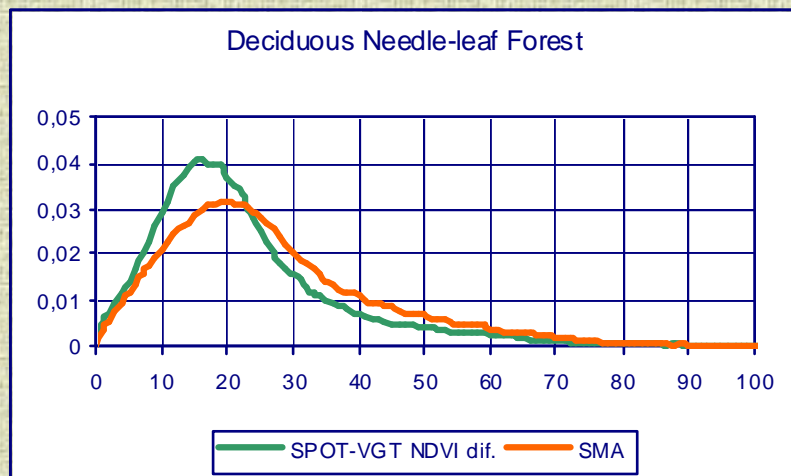
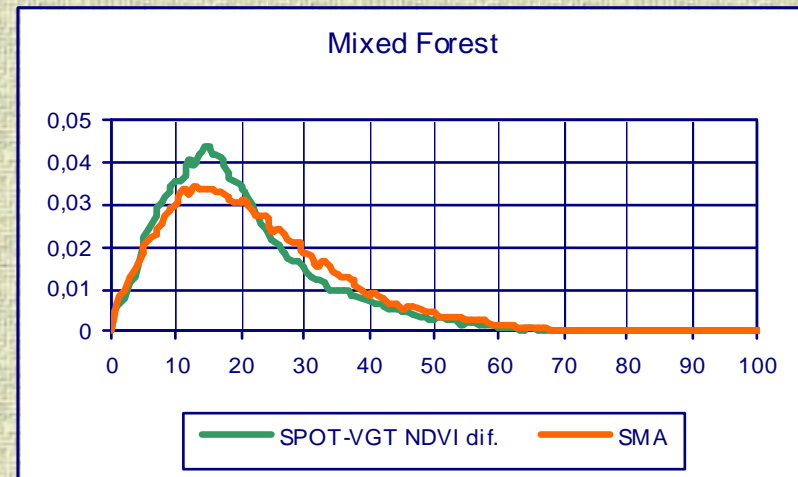
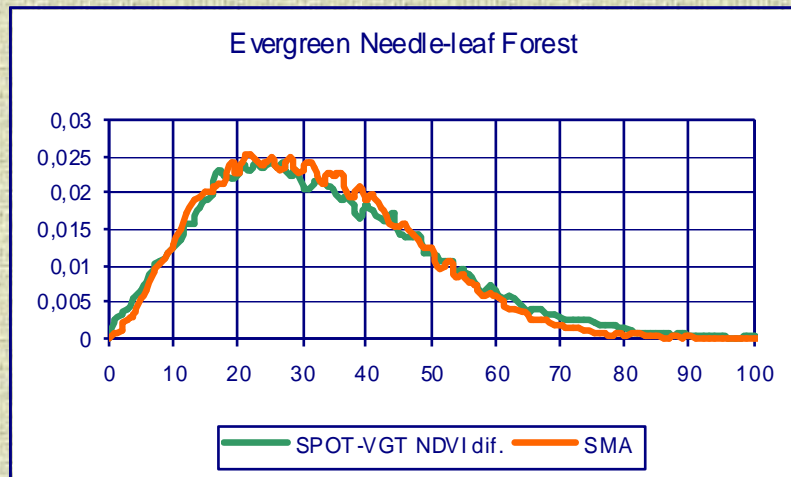
Spectral Mixture Analysis result



NDVI difference method result



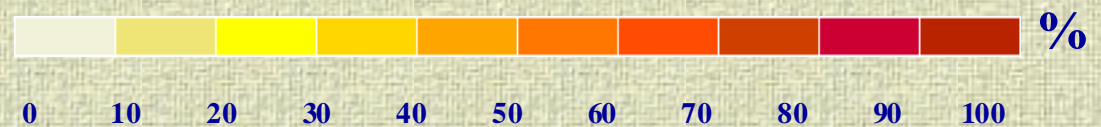
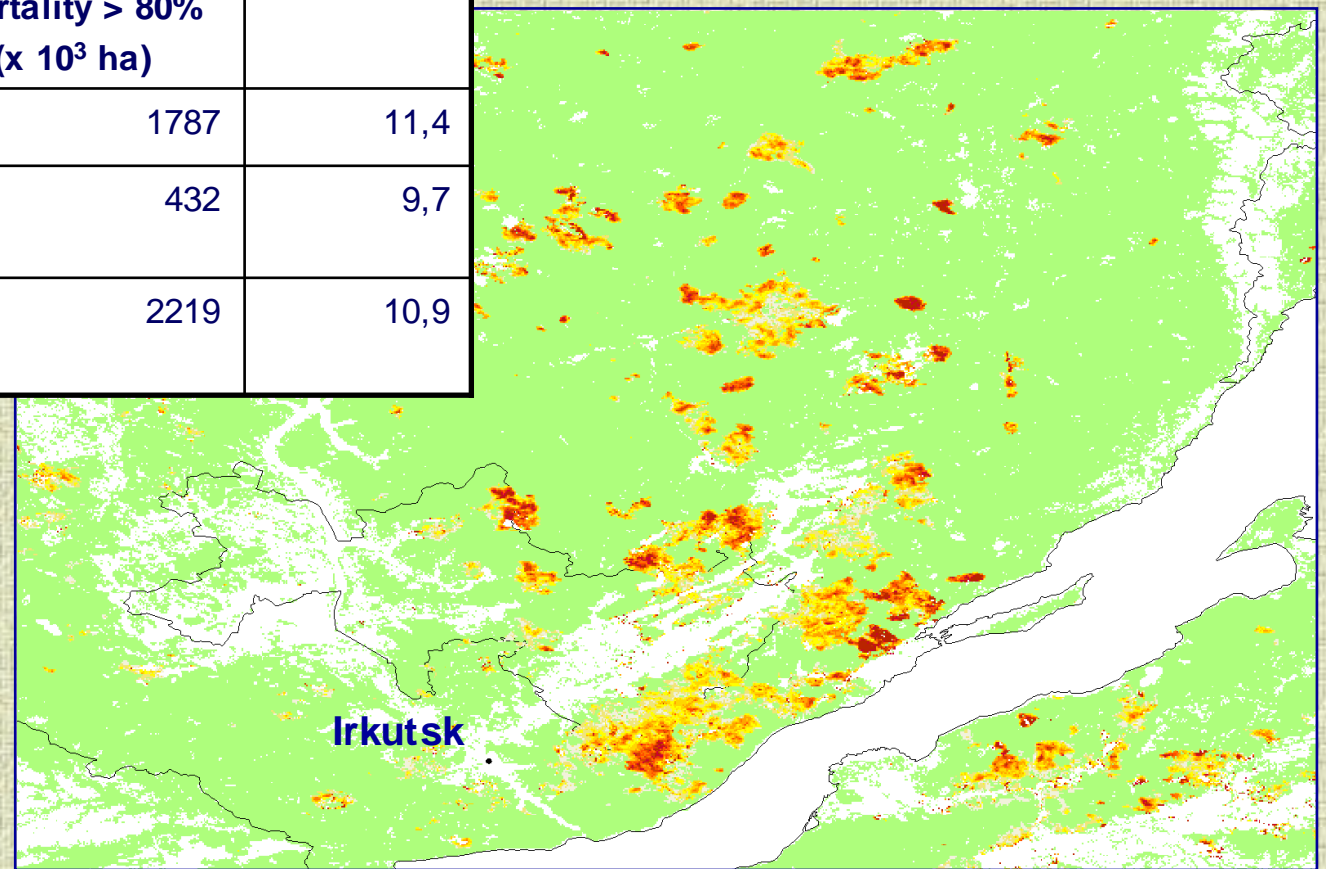
# Comparison of forest burn severity assessment from VEGETATION using two different methods





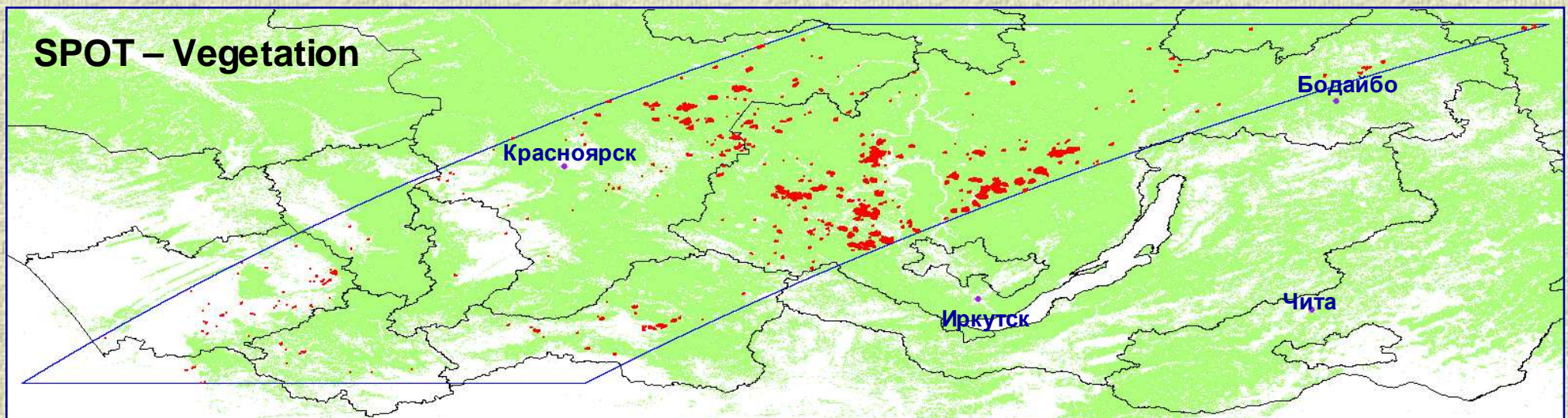
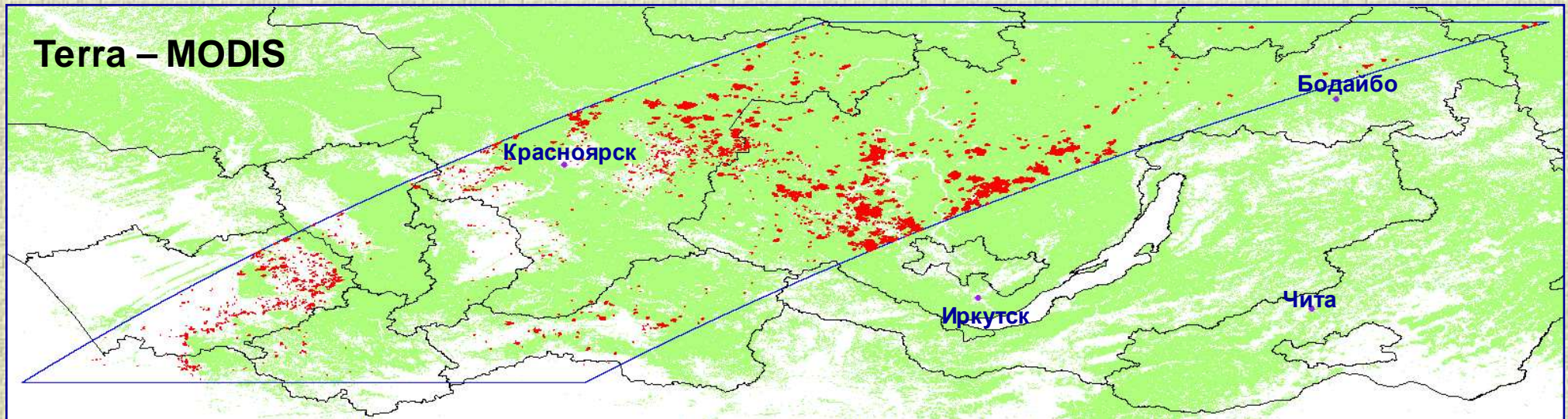
# Burnt severity assessment for 2003 using SPOT-Vegetation data (preliminary result)

Region	Burt area (x 10 <sup>3</sup> ha)	Area of burnt forest with trees mortality > 80% (x 10 <sup>3</sup> ha)	%
Siberia	15676	1787	11,4
Far East	4456	432	9,7
Asian part of Russia (in total)	20132	2219	10,9





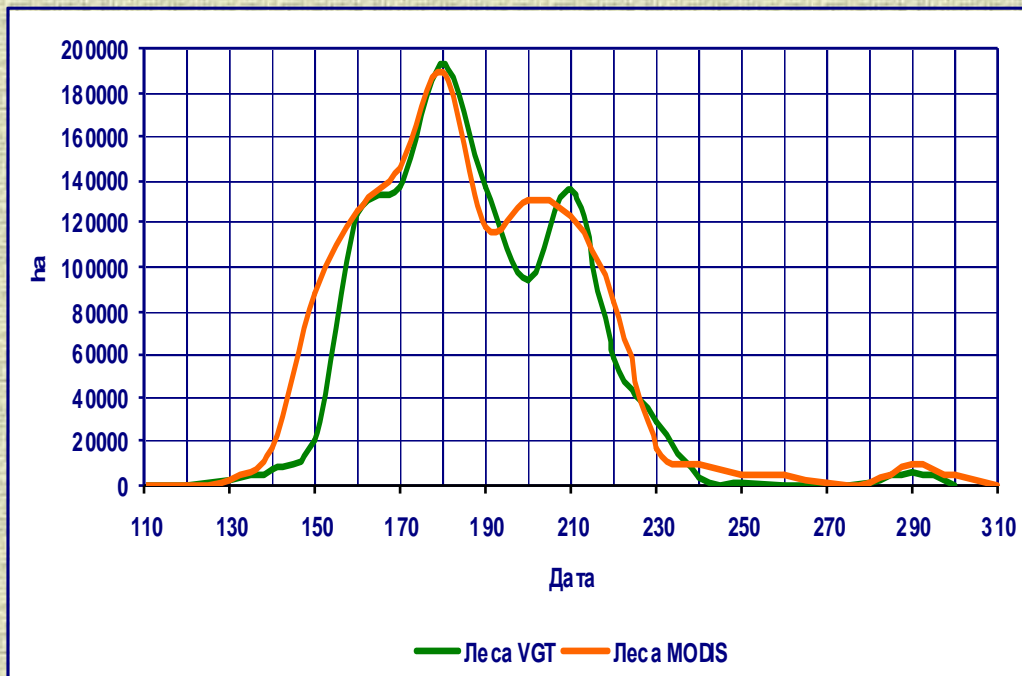
# Comparison of burnt area maps using SPOT-Vegetation и Terra-MODIS data (MODIS granule H23V03)



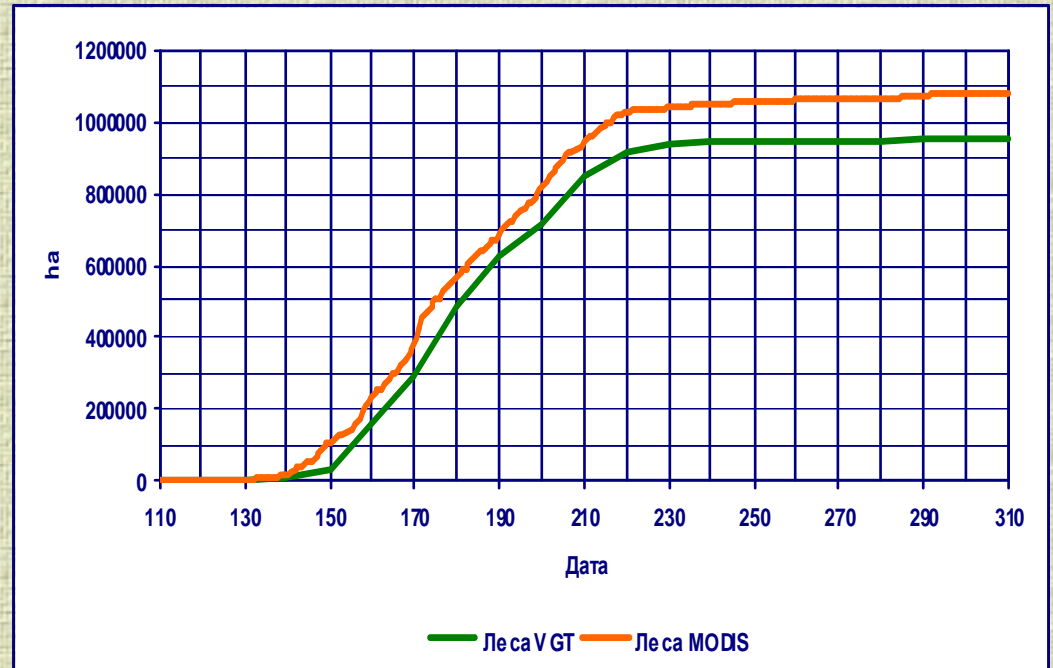


# Comparison of burnt area maps using SPOT-Vegetation и Terra-MODIS data (MODIS granule H23V03)

Burnt area by decades



Cumulative burnt area



$$S_{VGT} = 950.7 \times 10^3 \text{ ha}$$

$$S_{MODIS} = 1074.1 \times 10^3 \text{ ha}$$

$$(S_{MODIS} - S_{VGT}) / S_{MODIS} = 11.5\%$$



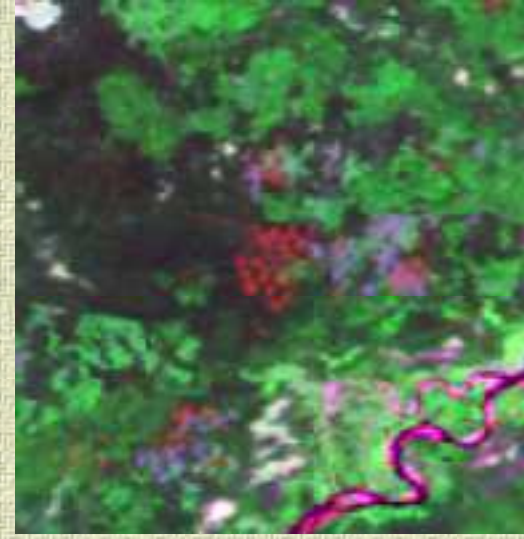
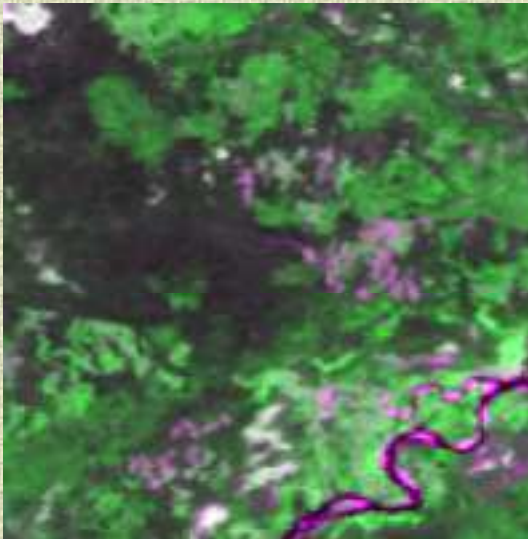
# Forest Logging Assessment





# Detection of logging in North European regions of Russia using MODIS

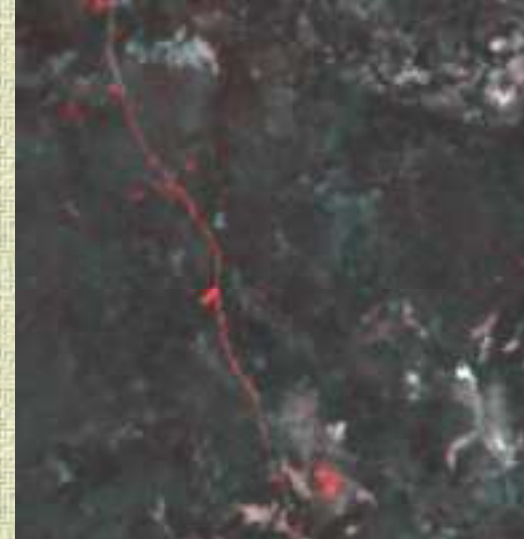
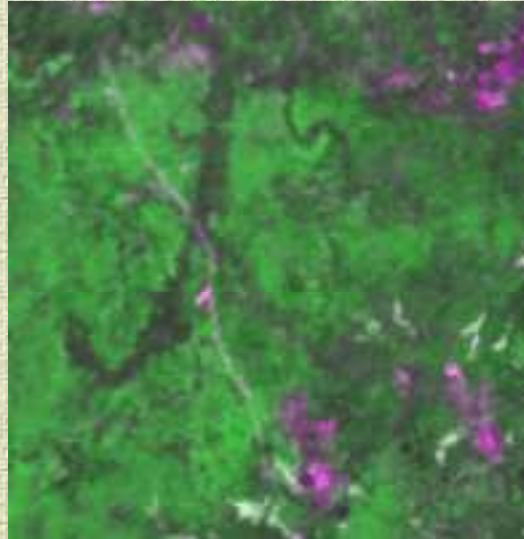
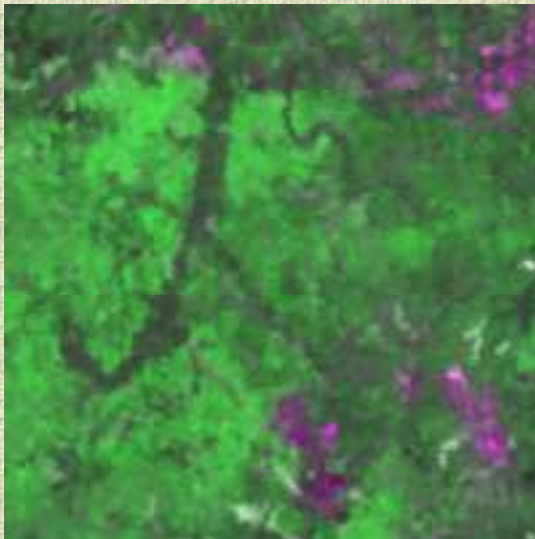
July 2002, RGB : Ch1-Ch2-Ch6    July 2005, RGB : Ch1-Ch2-Ch6



Detection of new clear-cuts in dark coniferous forest

RGB :

Ch1(2005)-  
Ch2(2002)-  
Ch6(2002)



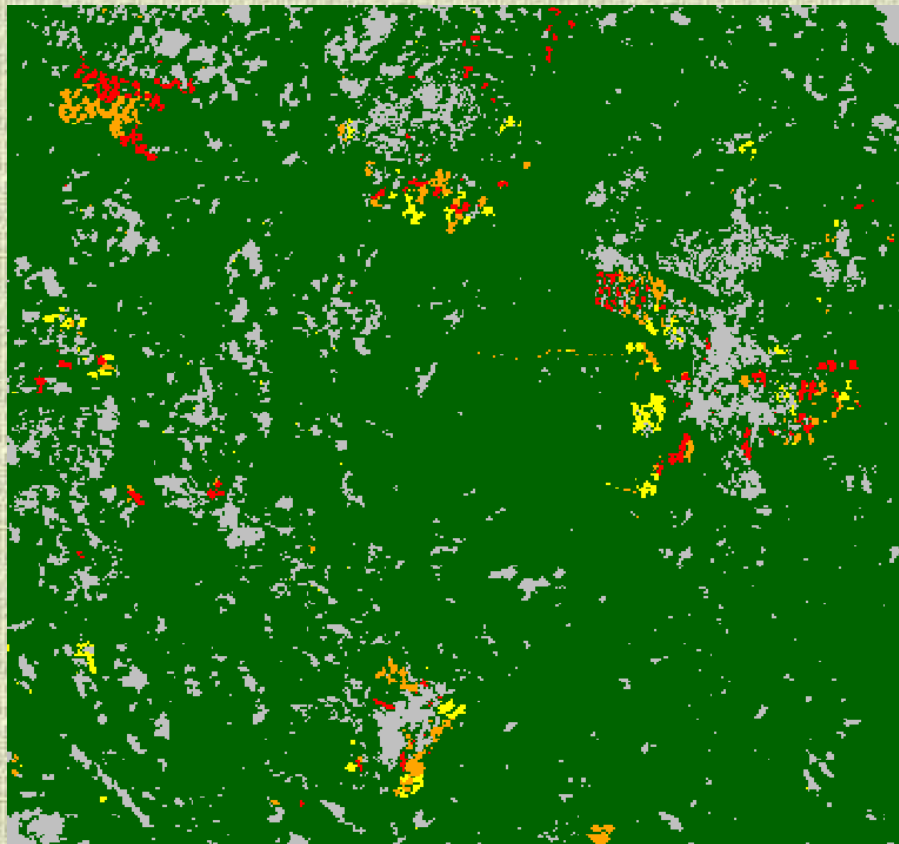
Detection of new road and clear-cuts in broadleaf forest

RGB :

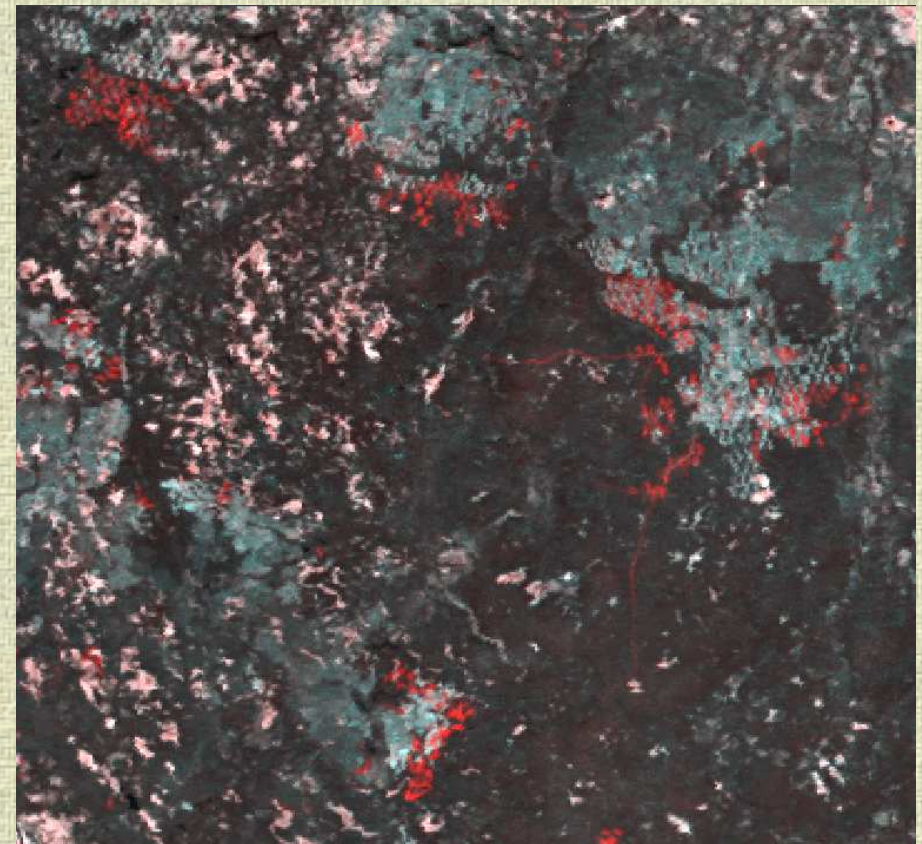
Ch1(2005)-  
Ch2(2002)-  
Ch1(2002)



# Detection of logging in North European regions of Russia using MODIS



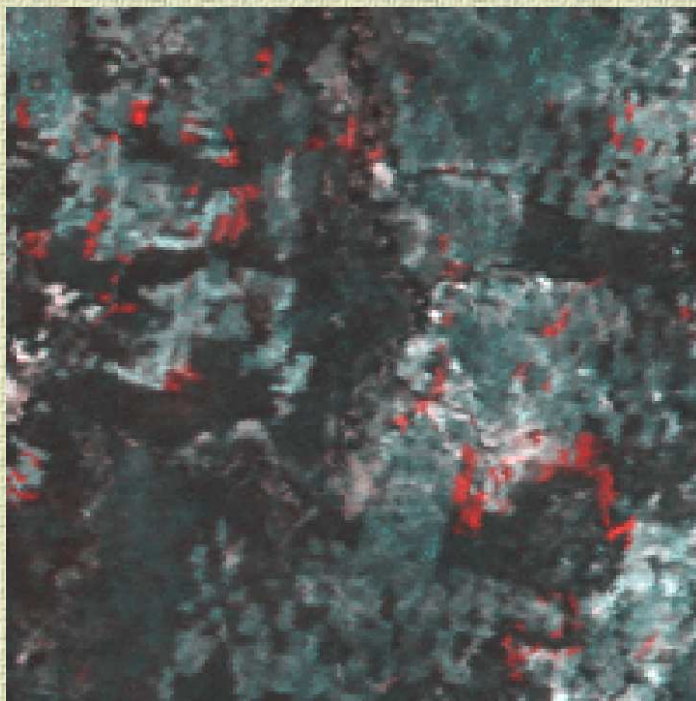
- Forest
- Non-Forest
- Logging 2002-2003
- Logging 2003-2004
- Logging 2004-2005



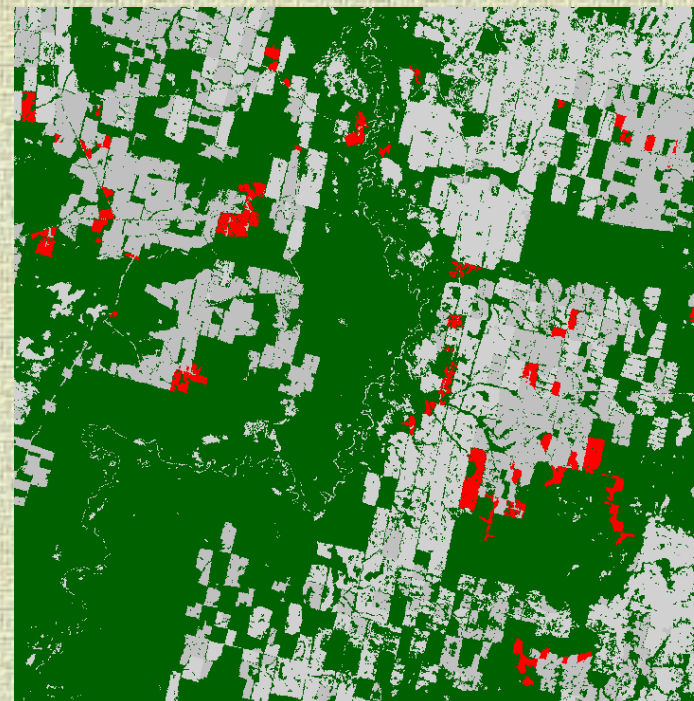
R – Red channel 2005; G,B - Red channel 2002



# Comparison of clear-cuts detectability using MODIS and high-resolution data



RGB synthesis of multi-temporal MODIS data  
(July 2002 and July 2005)



Clear-cuts detected using Landsat-ETM+ (2002)  
and Meteor-3M/MSU (2004) data

Clear-cur area (ha)	<= 5	5 - 10	10-15	15-20	20-25	=> 25	Total
Detected clear-cuts	92	104	108	108	54	140	606
<b>% of detected clear-cuts</b>	<b>9.2</b>	<b>35.0</b>	<b>64.3</b>	<b>83.7</b>	<b>81.8</b>	<b>95.2</b>	<b>33.6</b>
Missing clear-cuts	904	193	60	21	12	7	1197
<b>% of missing clear-cuts</b>	<b>90.8</b>	<b>65.0</b>	<b>35.7</b>	<b>16.3</b>	<b>18.2</b>	<b>4.8</b>	<b>66.4</b>

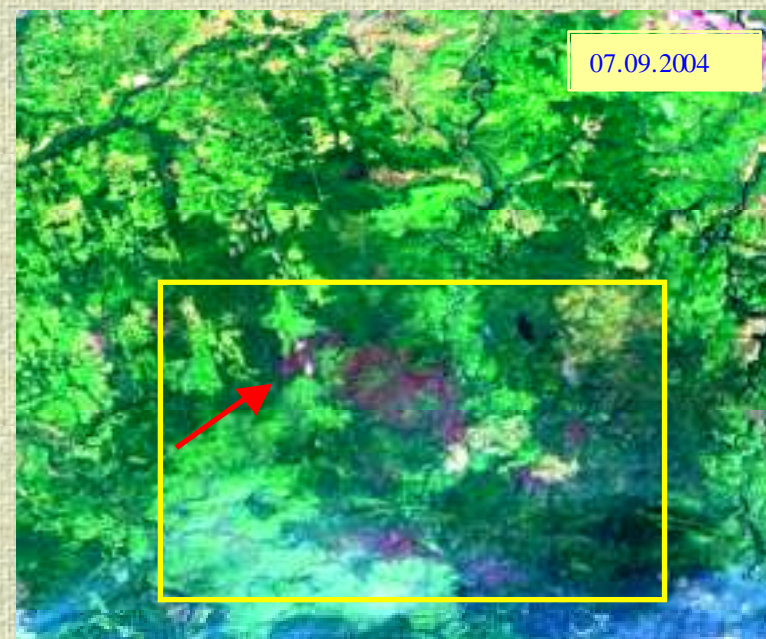
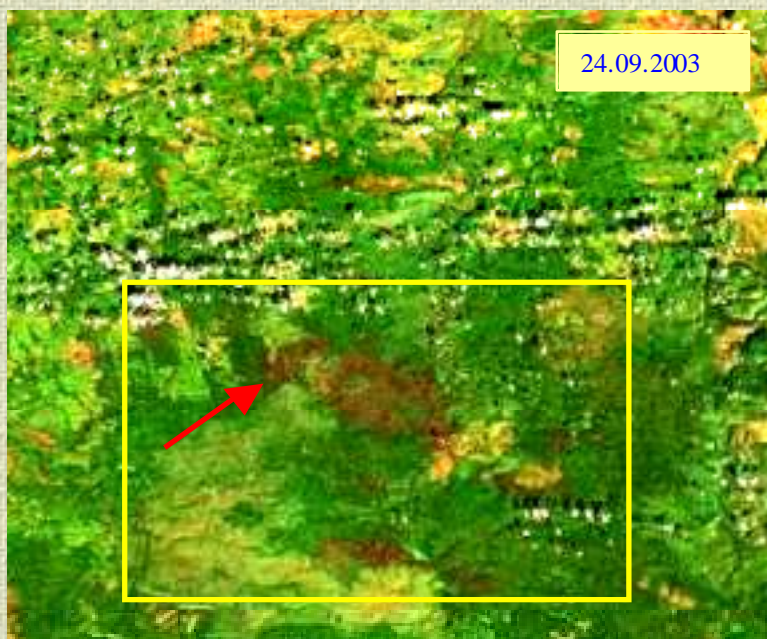
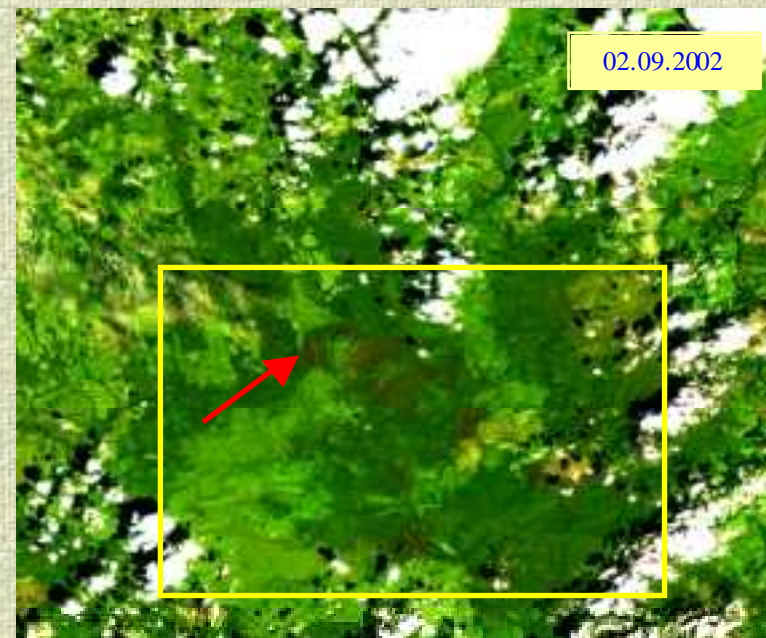
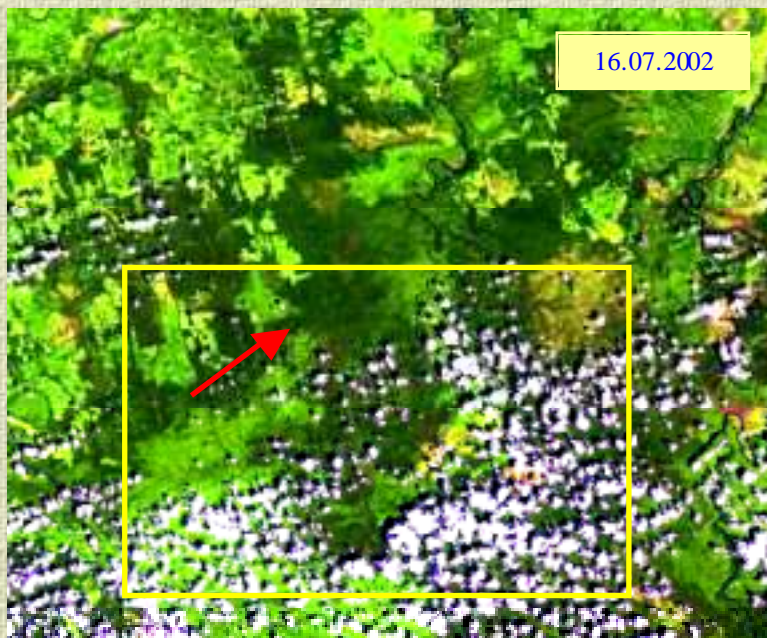


# Forest Disturbances by Insects



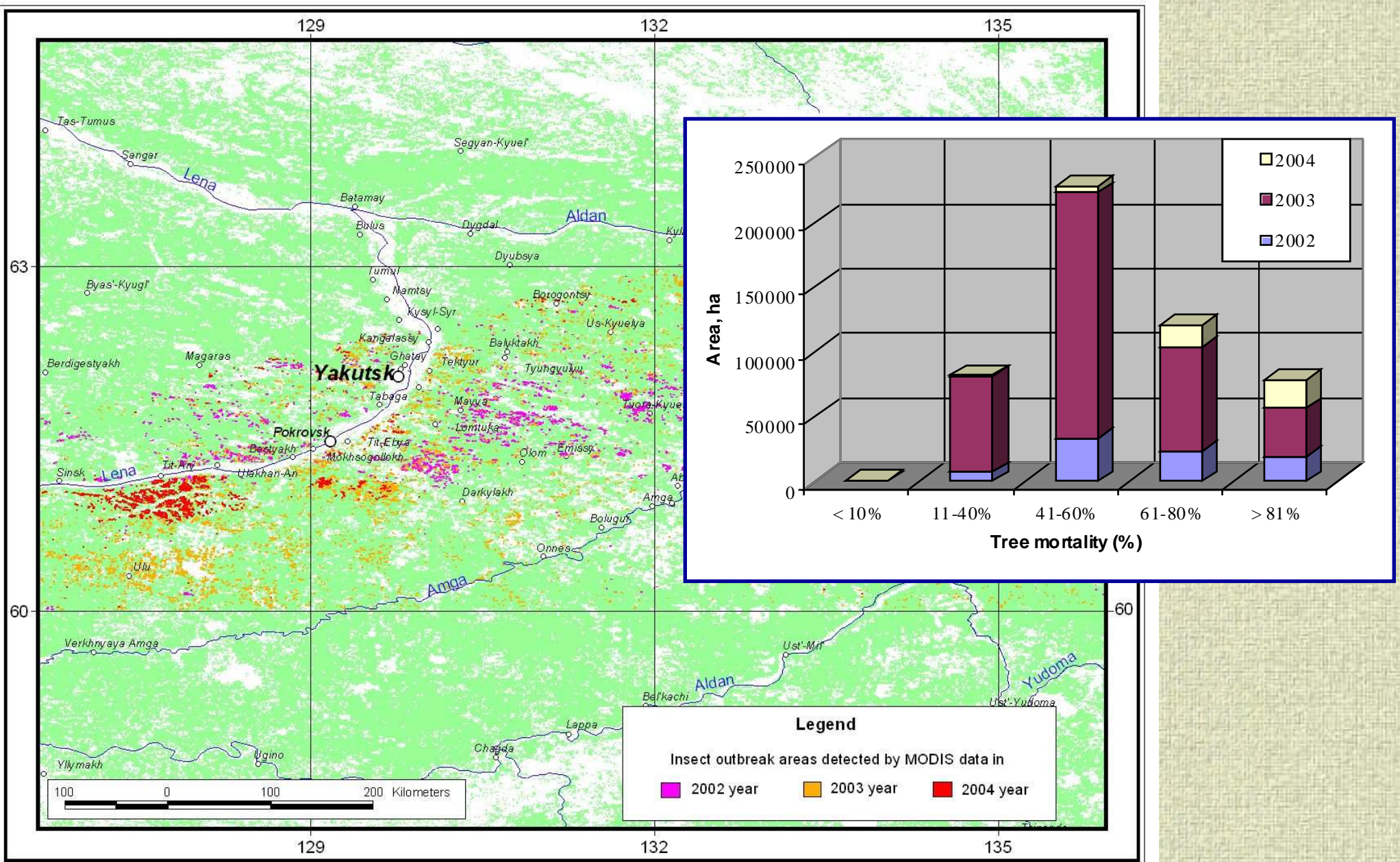


# Dynamic of forest disturbances by insects' out-brakes from MODIS





# Mapping of insects induced forest disturbances using MODIS

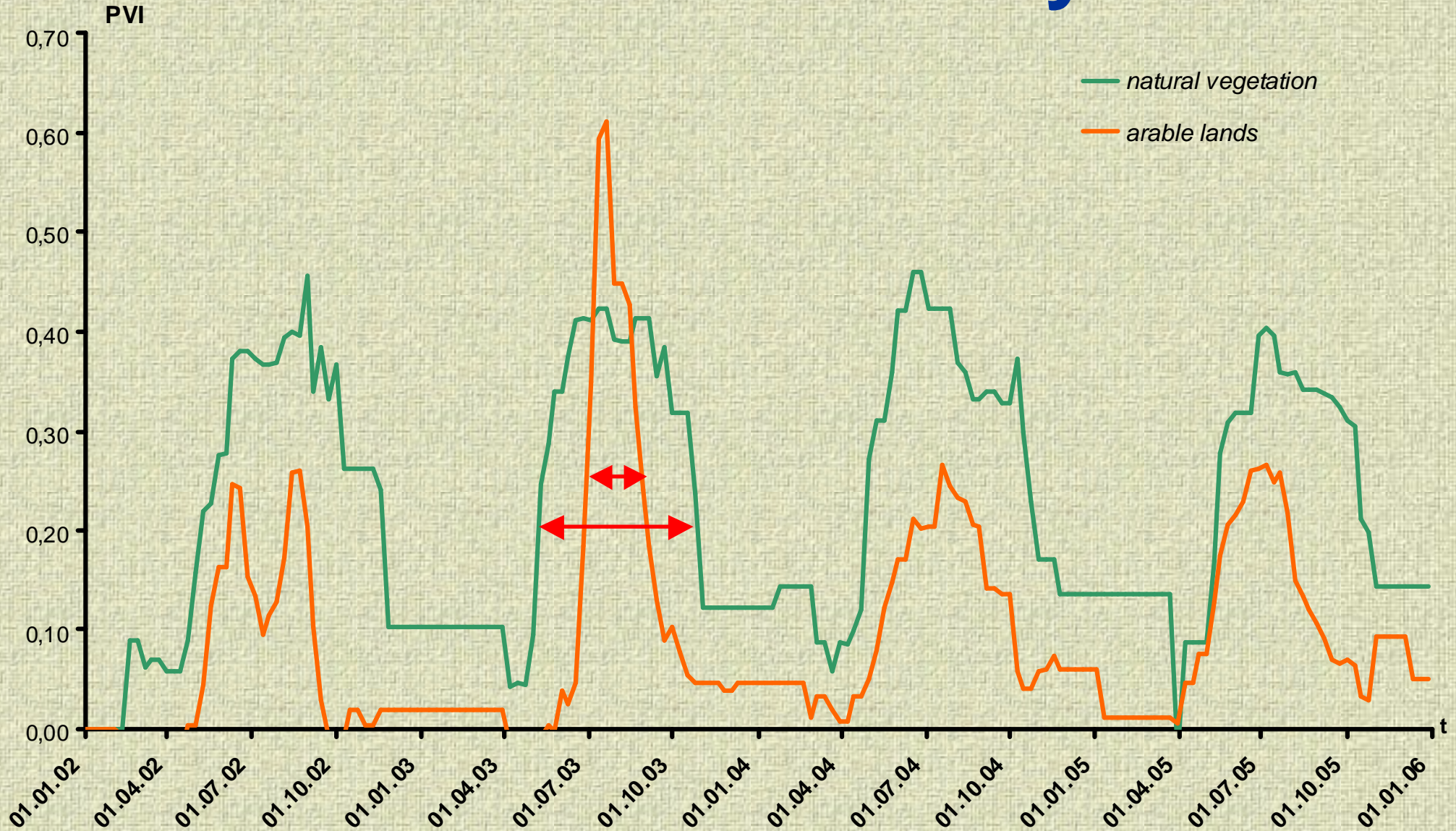




# **Monitoring of Agricultural Lands**



# PVI time-series analysis

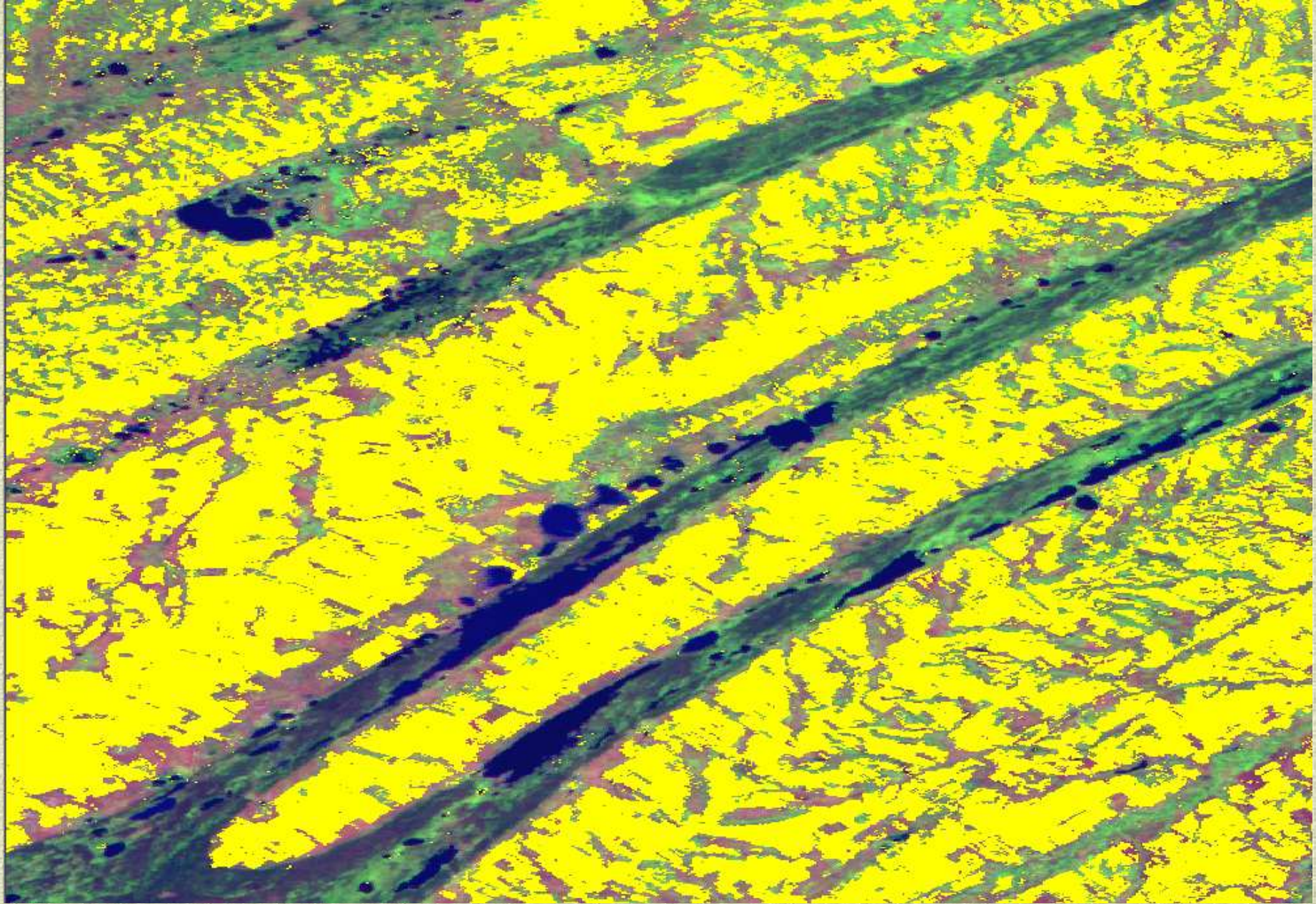


□ Inter-annual PVI dynamic similarity assessment

□ Phenological features retrieval: start, max, half senescence, length of season

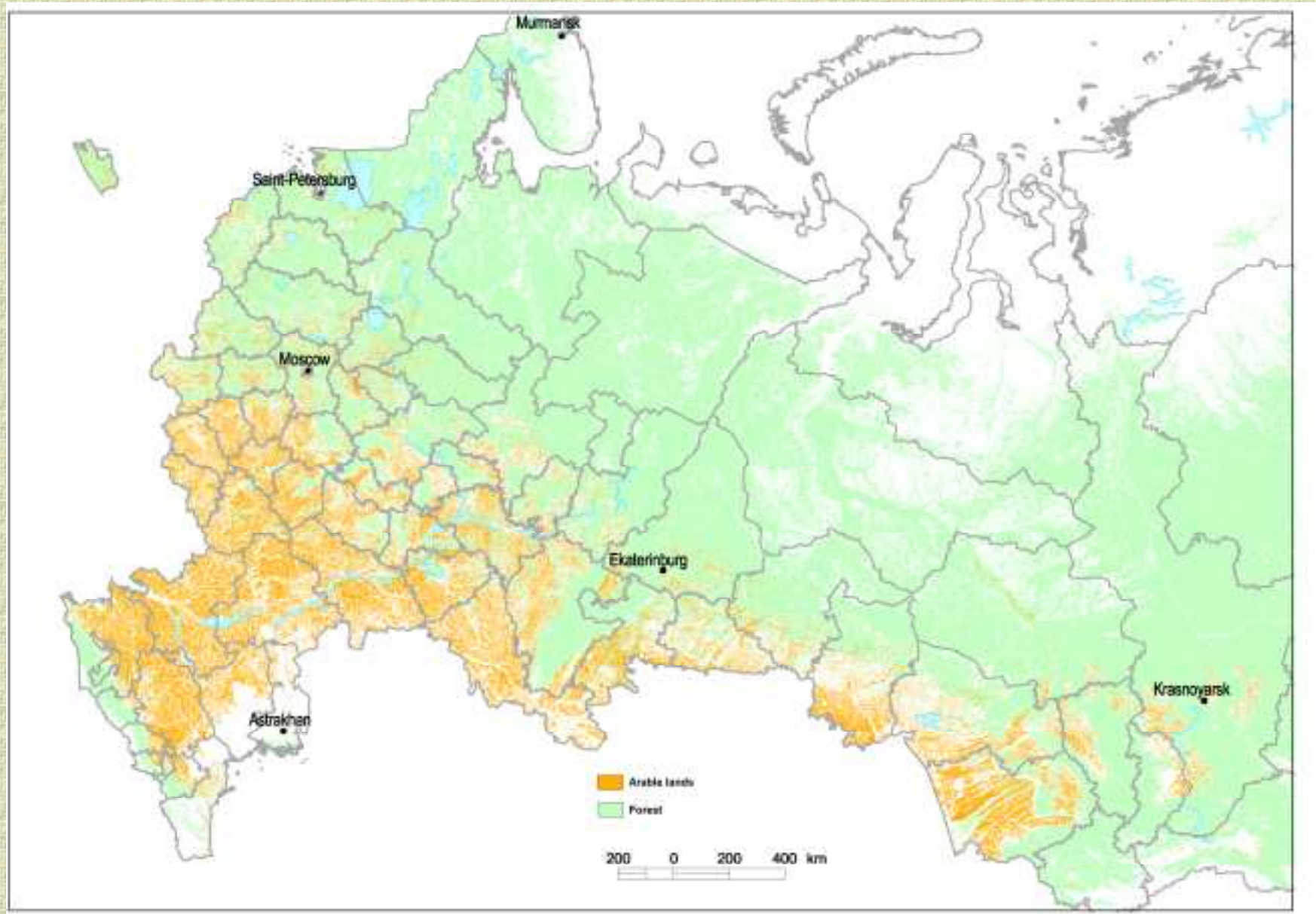


# MODIS derived arable lands map of Russia : Altaisky kray





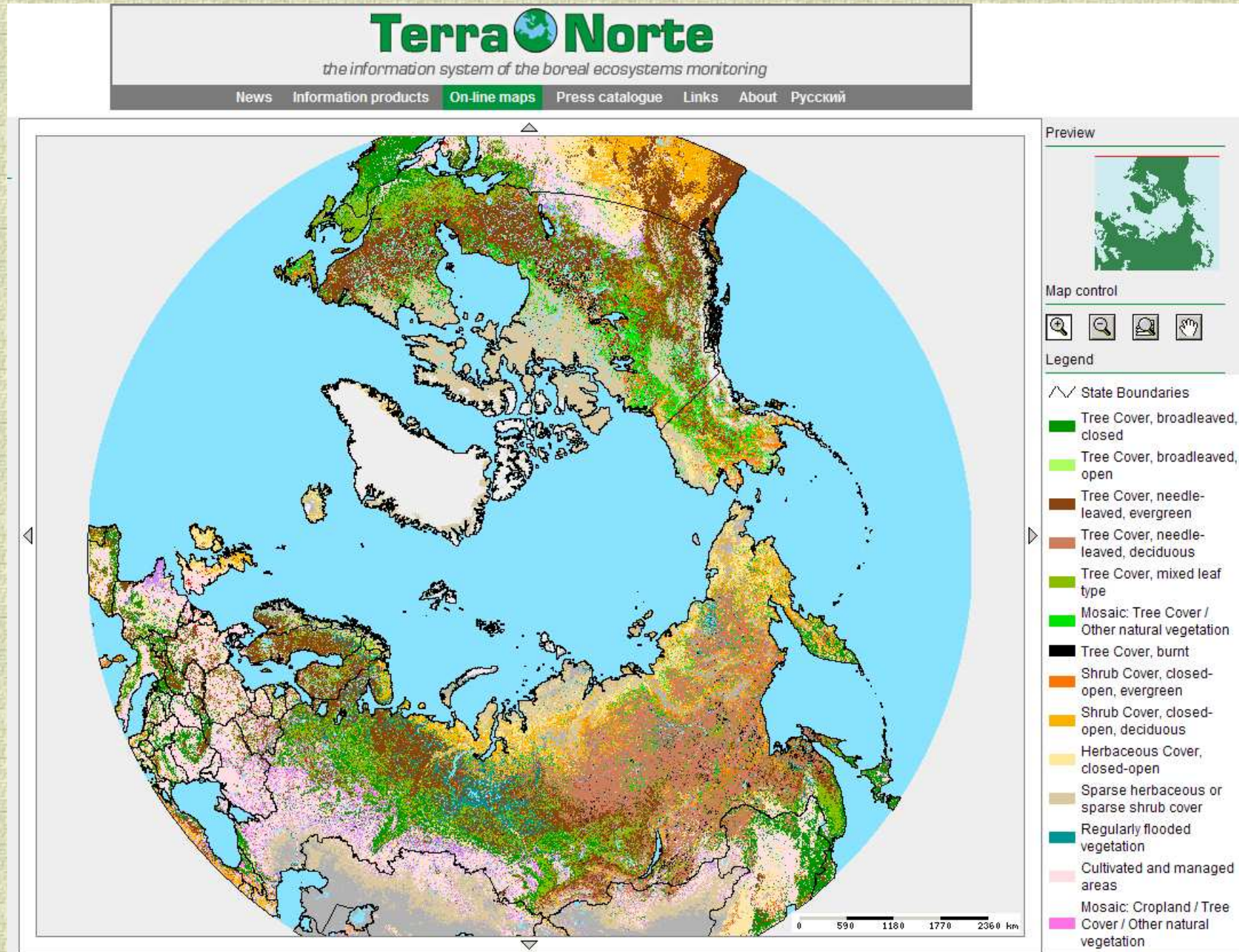
# An arable lands map for Russia generated from MODIS data



Draft product, status on July 2006. Mapping for some regions is in progress.



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- Сельскохозяйственные культуры, 2002 г.
- Сельскохозяйственные культуры, 2003 г.
- Сельскохозяйственные культуры, 2004 г.
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- Land cover for the year 2001
- Clearcuts
- Regions enterprises boundaries
- Forest enterprises boundaries

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- Non-forest
- Clear-cuts during 1989-1995
- Clear-cuts during 1995-2001
- Clear-cuts during 2001-2002

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- Rivers
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- Evergreen Needleleaf Forest
- Broadleaf Forest
- Mixed Forest
- Deciduous Broadleaf Forest
- Broadleaf Deciduous Shrubs
- Needleleaf Evergreen Shrubs
- Humid Grasslands
- Steppe
- Bogs and Marsh
- Palsa Bogs
- Riparian Vegetation
- Barren and Prostrate Shrub Tundra
- Sedge Tundra
- Shrub Tundra
- Recent burns

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