LONG-TERM DYNAMICS OF FOREST DAMAGE CAUSED BY SQUALLS, TORNADOES AND HEAVY SNOWFALLS ON THE NORTH-EAST OF EUROPEAN RUSSIA (with Landsat images)

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MOTIVATION

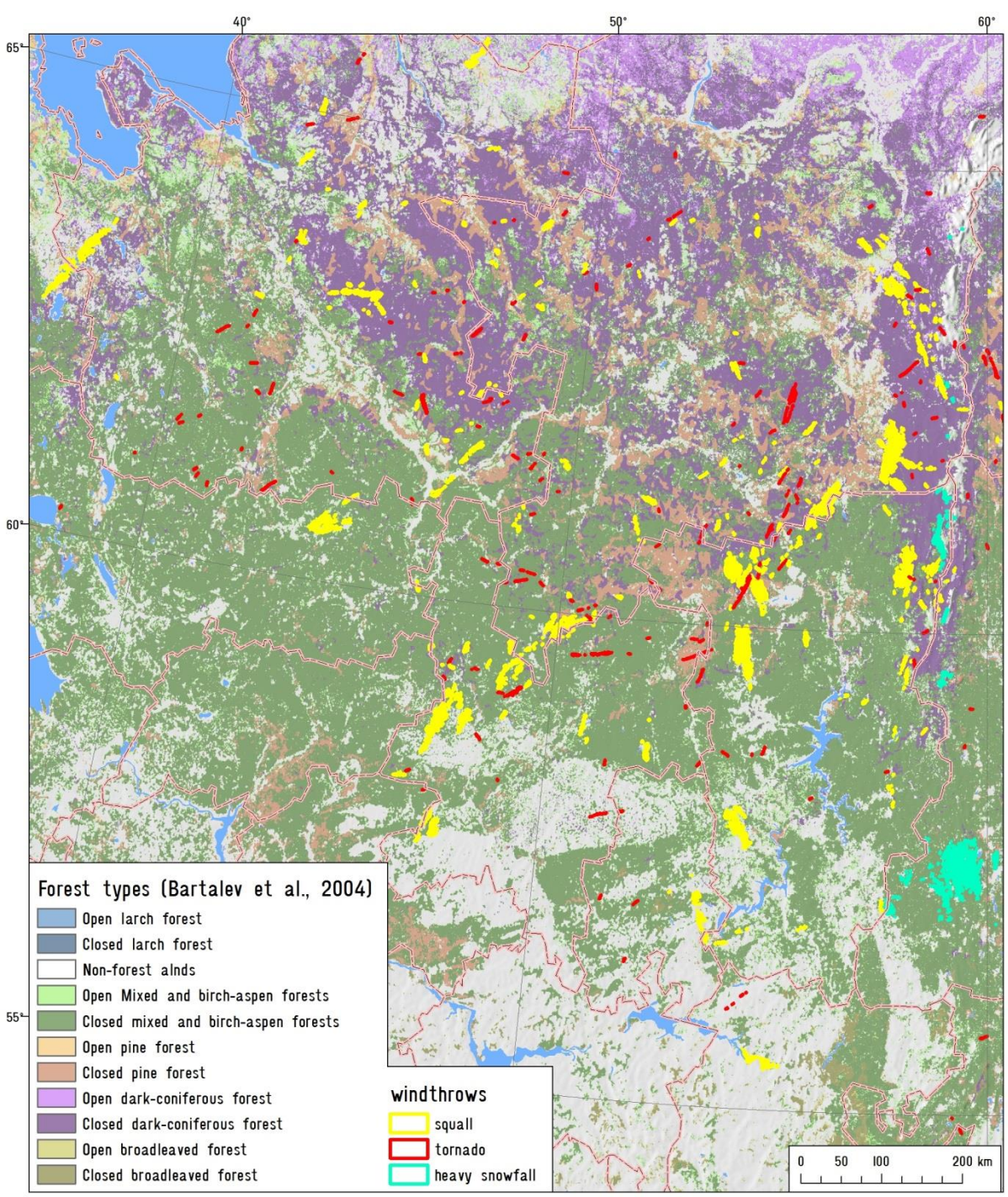
- Strong wind, squalls and tornadoes caused significant forest damage in European Russia. **Only in 2009-2012, total windthrows area is estimated at 2000 km^2**. Large-scale forest damage in European Russia was caused by severe storms 07 June 2009 (~120 km^2), 16 June 2009 (~170 km^2), 27 June 2010 (>500 km^2), 29 June 2010 (>500 km^2), and also 18 July 2012 (~270 km^2)
- An observed increase of storm-induced forest damage can be associated with climate change. In particular, severe convective storms which caused the most catastrophic windthrows are observed in the environment of abnormally hot weather (2010 summer heat wave in the European Russia, 2012 summer heat wave in the Ural).

PURPOSE OF THE STUDY

- Estimate long-term dynamics of forest damage caused by strong wind and tornadoes in the European Russia from 1984 to present, with the use of 30-m resolution Landsat images.
- Complement the climatology of strong squalls and tornadoes in the forest zone of European Russia

INITIAL DATA

- Global Forest Change (GFC) data (Hansen et al., 2013) for 2001-2016
- GFC (Forest Loss Year) is the free-available Landsat-based dataset on forest losses (without determination of their types), with 30 m spatial resolution, one year time accuracy and annual update (*http://earthenginepartners.appspot.com/science-2013-global-forest*).
- Eastern-Europe forest cover change (EEFCC) data (Potapov et al., 2015) for 1984-2000. EEFFC dataset contains the data on forest losses for 1985-1988 and 1989-2000 (without determination of their types and year)
- Russia's Forests map (Dominating Forest Types and Their Canopy Density) with 300 m spatial resolution, based on Terra/Aqua MODIS images (Bartalev et al., 2004)
- LANDSAT TM, ETM+ and OLI images for 1984-2016, obtained from USGS (*https://earthexplorer.usgs.gov/*).
- High-resolution satellite images obtained from public map services such as Google.Maps, Yandex.Maps, Bing Maps, ESRI (after 2000).

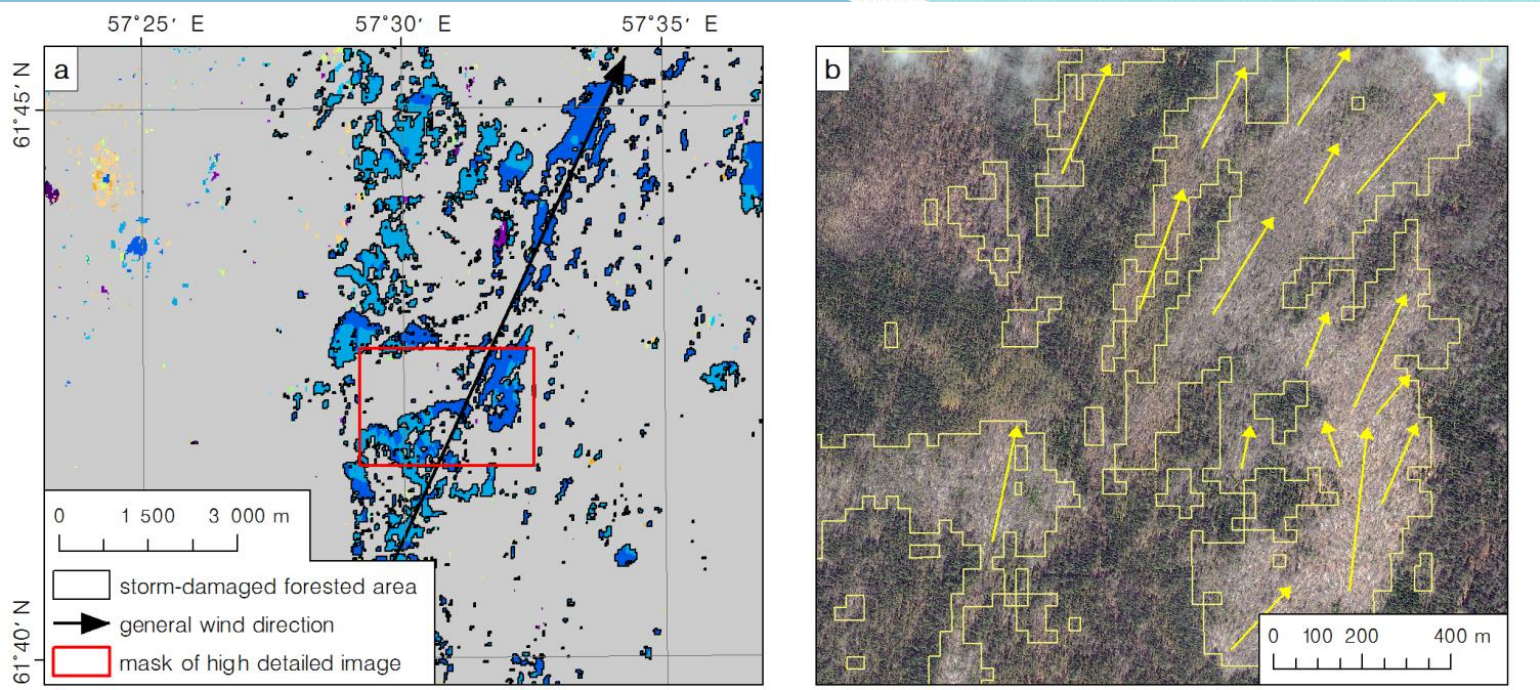


STUDY AREA (EUROPEAN RUSSIA AND URAL)

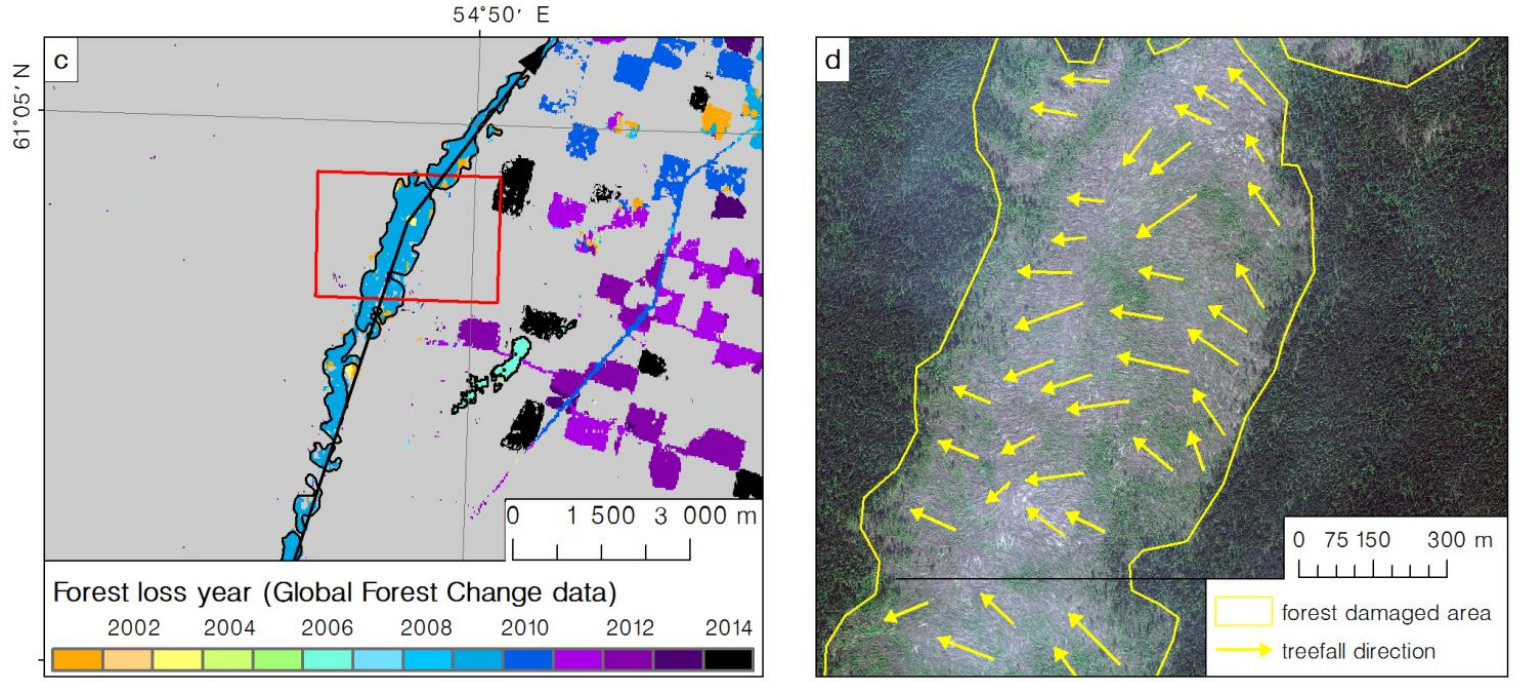
In this study, we present the windthrows database for North-East of European Russia (Komi Republic, Udmurt Republic, Perm and Kirov regions)

Windthrows identification by GFC data (2001-2016)

- 182 windthrows, with total area of **734,2 km^2**
- 90 windthrows caused by squalls and downbursts (591,7 km^2).
- 86 tornado-induced windthrows (100 km^2)
- 6 windthrows caused by wind-snow event (08 Oct 2015), with an area of 42,5 km^2
- Windthrows date determination – by Landsat images and other data sources (media reports, meteorological satellite images, CFS reanalysis data)
- Size threshold – 25 ha for windthrows caused by squalls and 5 ha for tornado-induced windthrows



Windthrow caused by squall (07 June 2009)

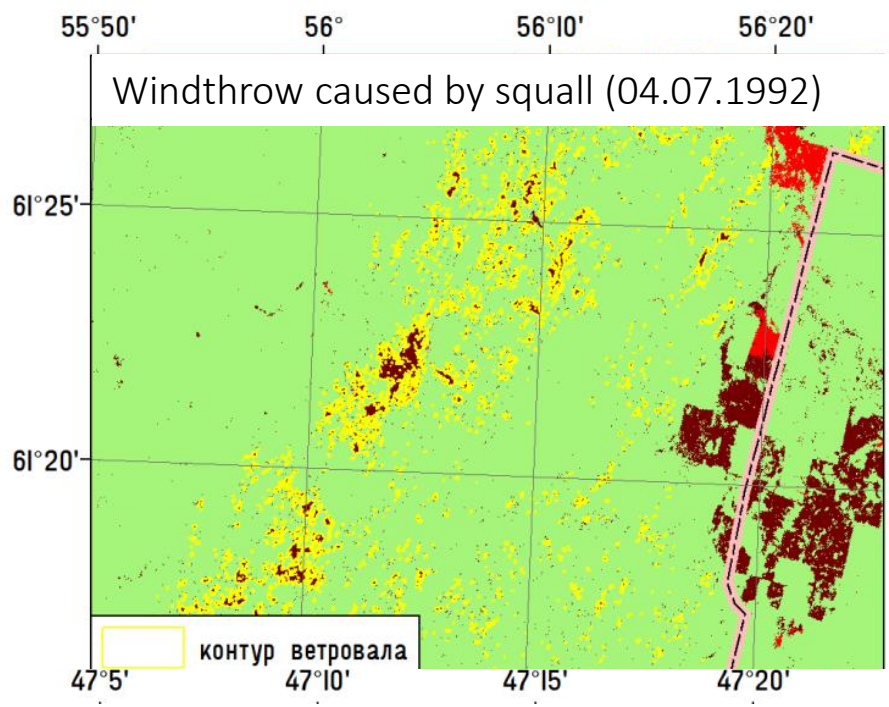


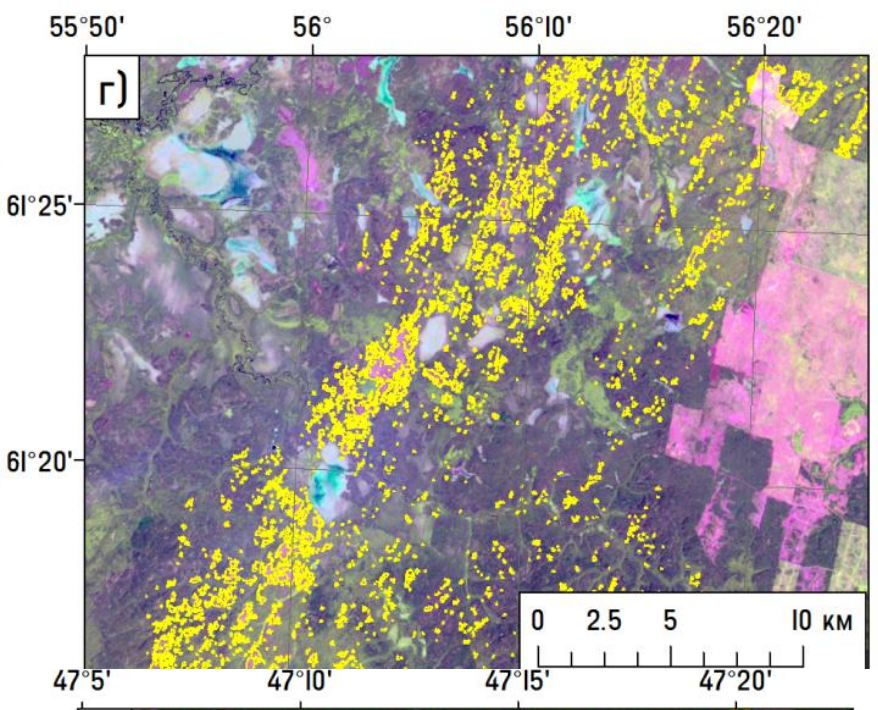
Windthrow caused by tornado (07 June 2009)

Windthrows identification by EEFCC data (1985-2000)

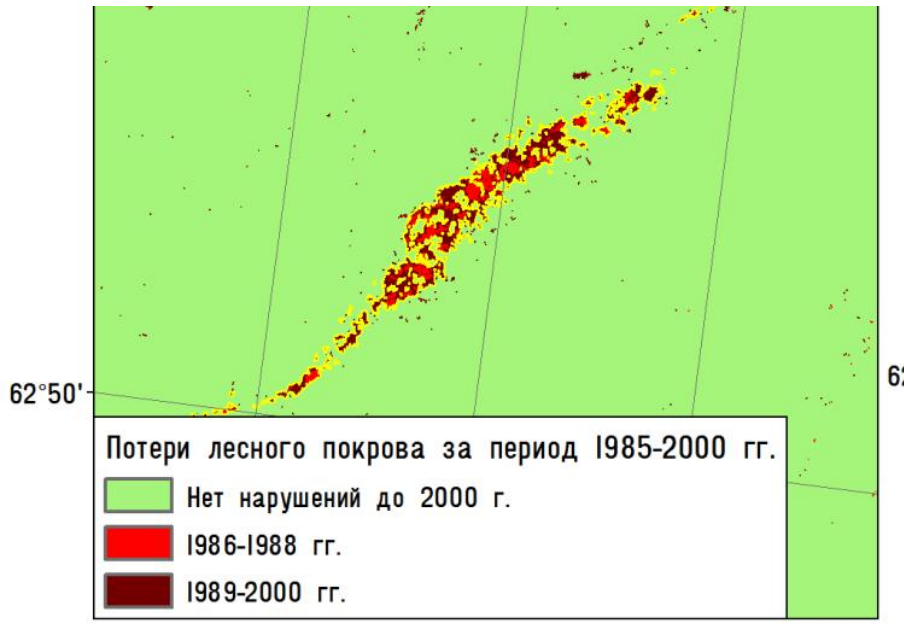
- 74 windthrows (in total), with an area of **293 km^2**
- 48 windthrows caused by squalls and downbursts (270,6 km^2)
- 25 tornado-induced windthrows (20,2 km^2)
- One windthrows caused by wind-snow event (06 June 1995), with an area of 2 km^2 in the Perm region (and ~ 200 km^2 in the Sverdlovsk region)
- Windthrows date determination – by Landsat images and other data sources (media reports, meteorological satellite images, CFS reanalysis data, **without high-resolution images**)
- Size threshold – 25 ha for windthrows caused by squalls and 5 ha for tornado-induced windthrows

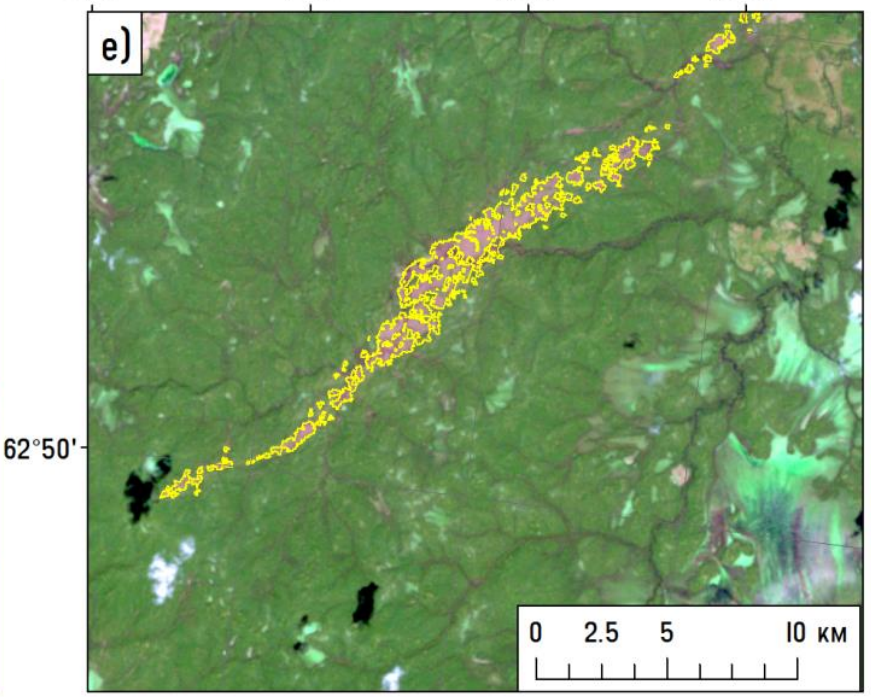
Windthrow caused by squall (04.07.1992)



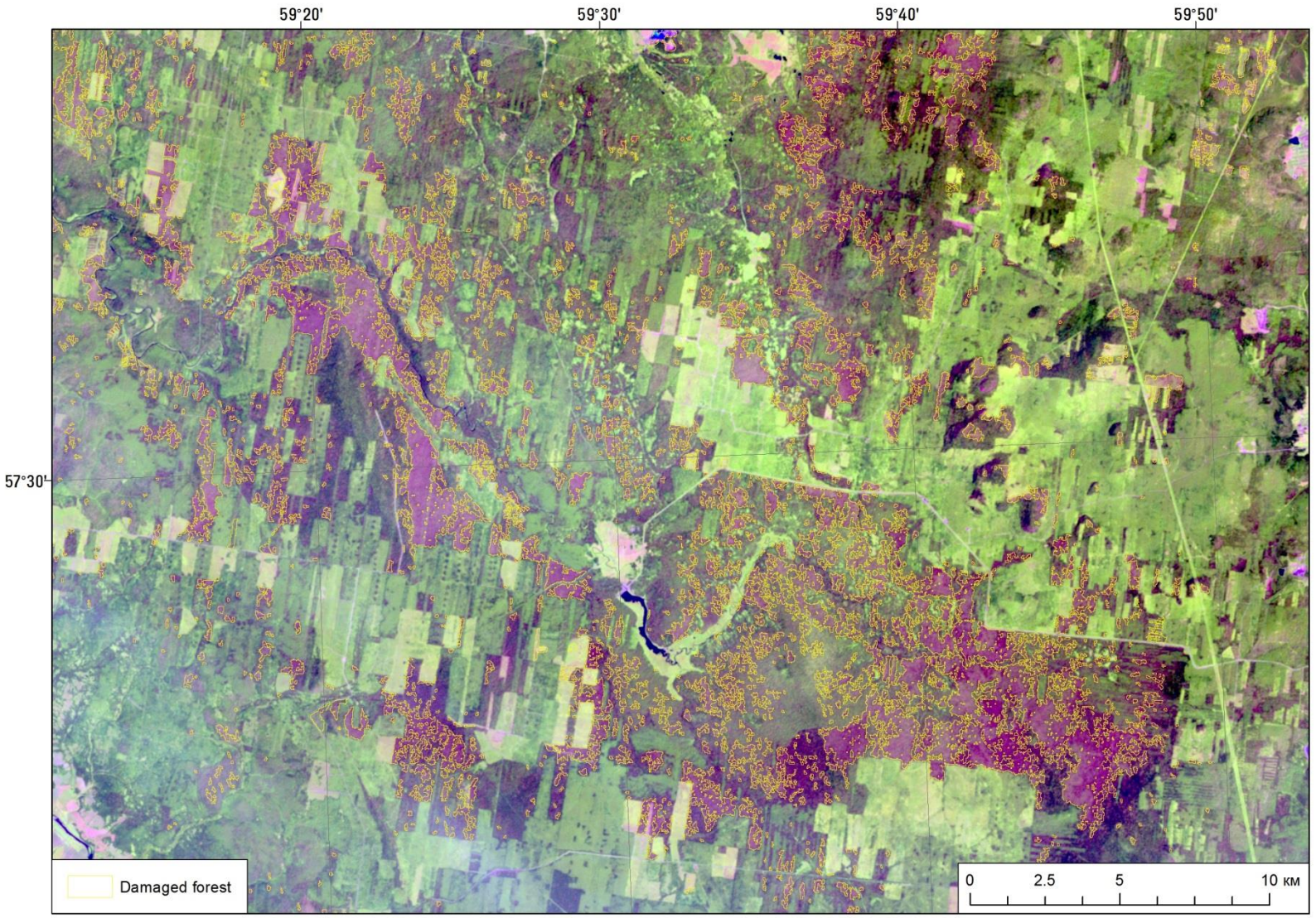


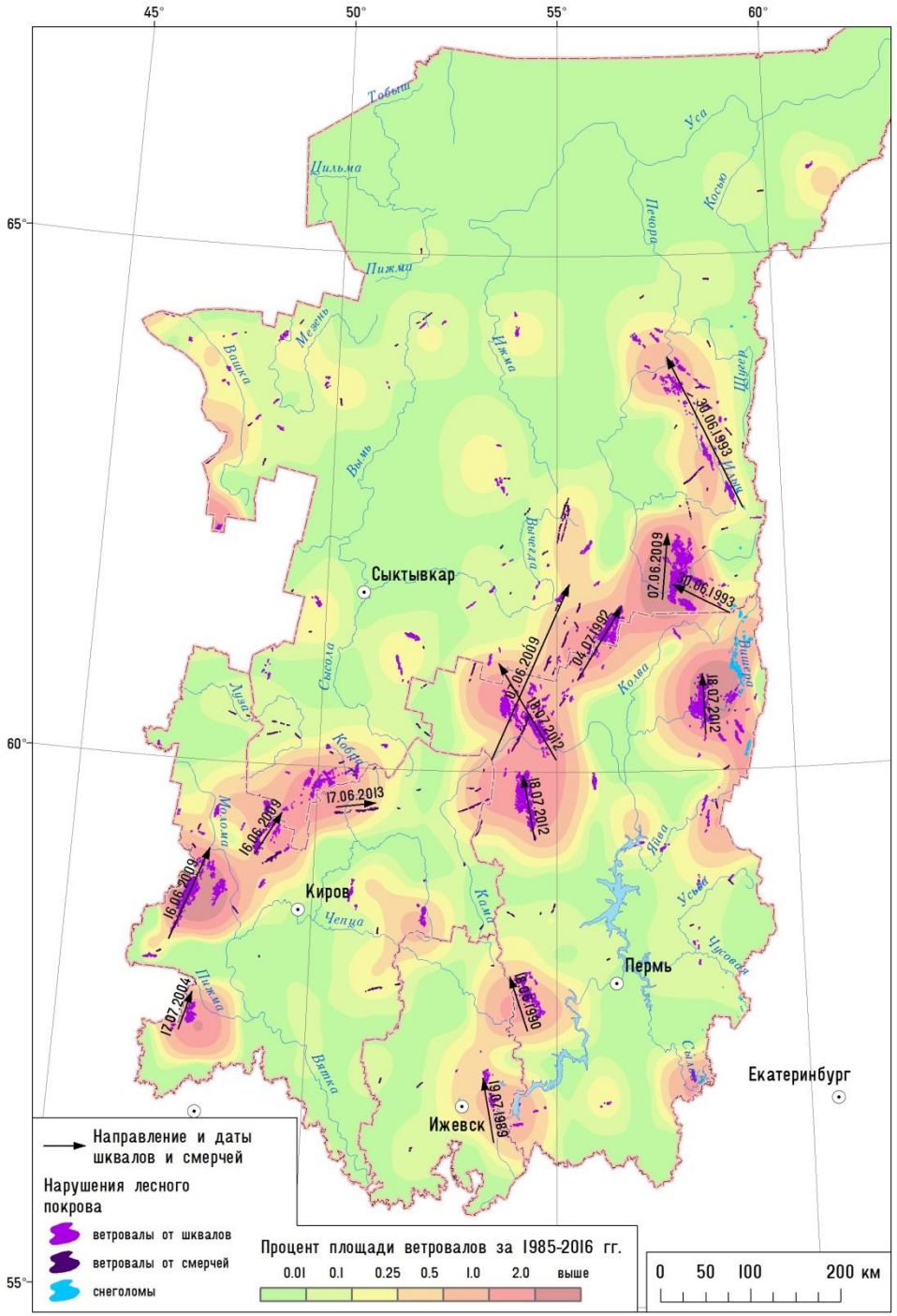
Tornado-induced windthrow (24.07.1988)





Catastrophic windthrow caused by severe wind (26 m/s) with heavy snowfall (up to 50 mm/24h) in Visim natural reserve (6 June 1995, Sverdlovsk region)



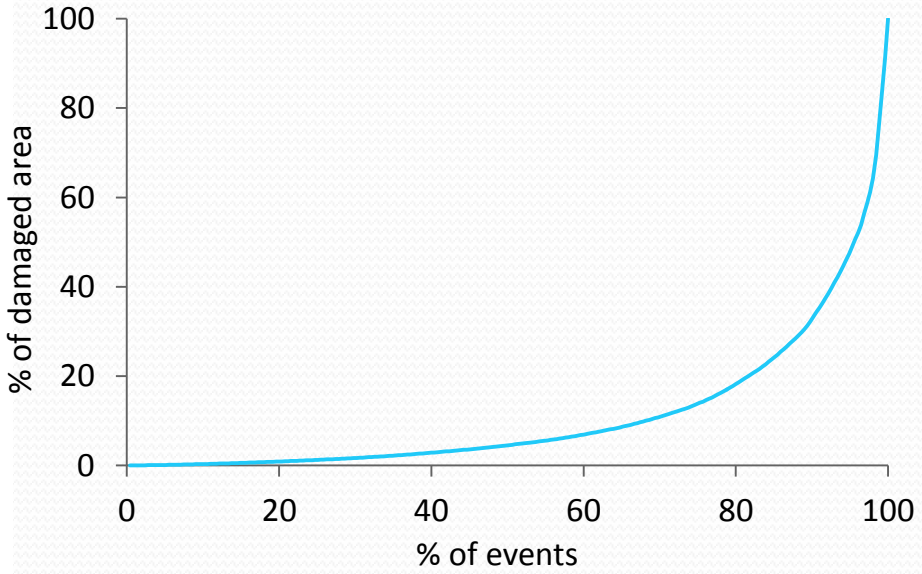


Total damage of windthrows in the North-East of European Russia (% of forest-covered area) and area distribution (Lorenz curve)

Average windthrow area – 4,01 km^2

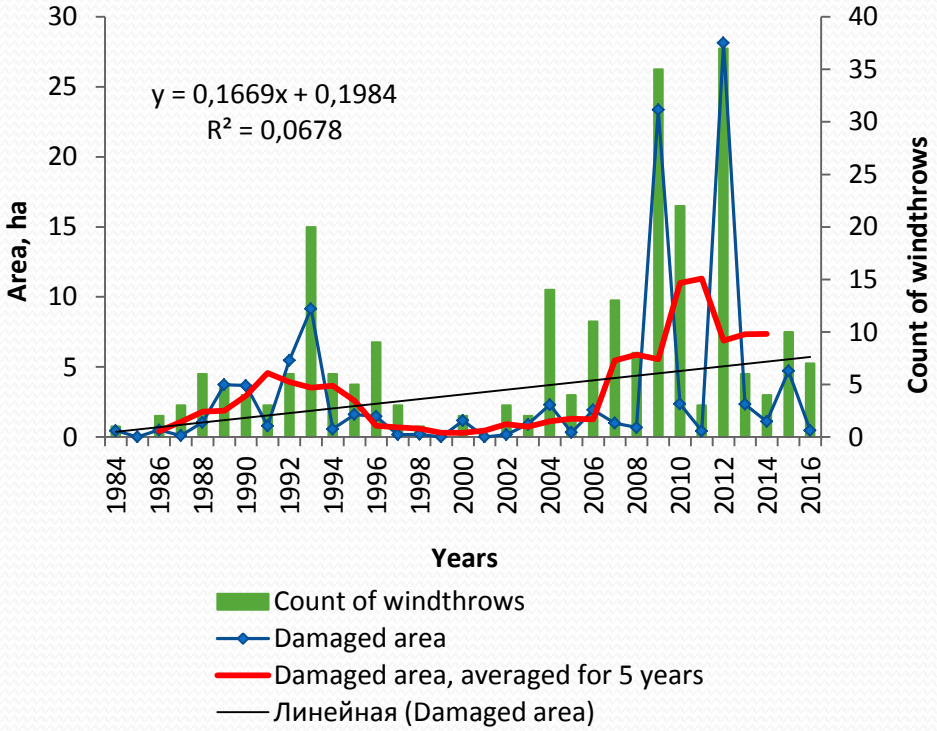
Median windthrow area – 0,77 km^2

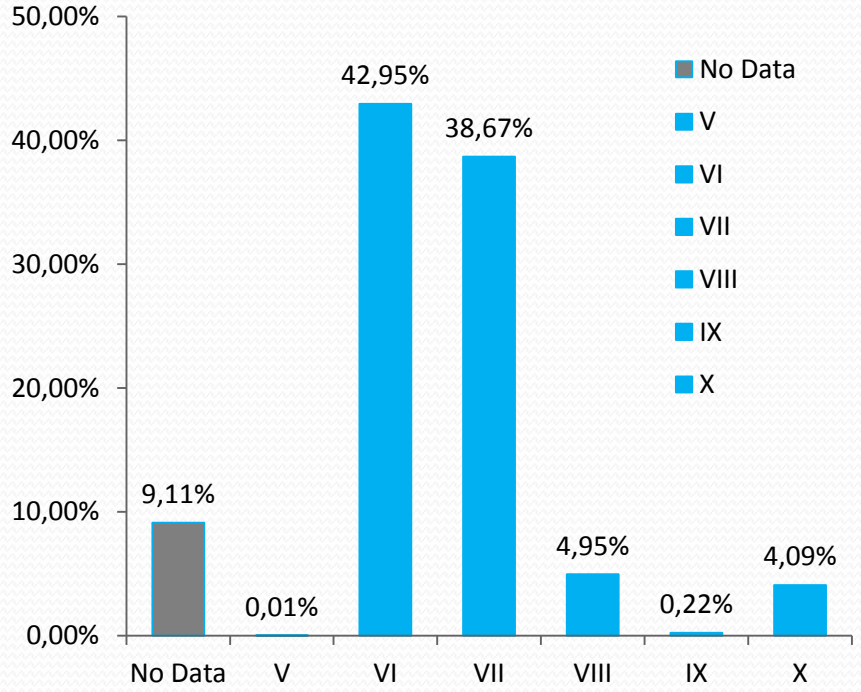
Maximum windthrow area – 85,92 km^2



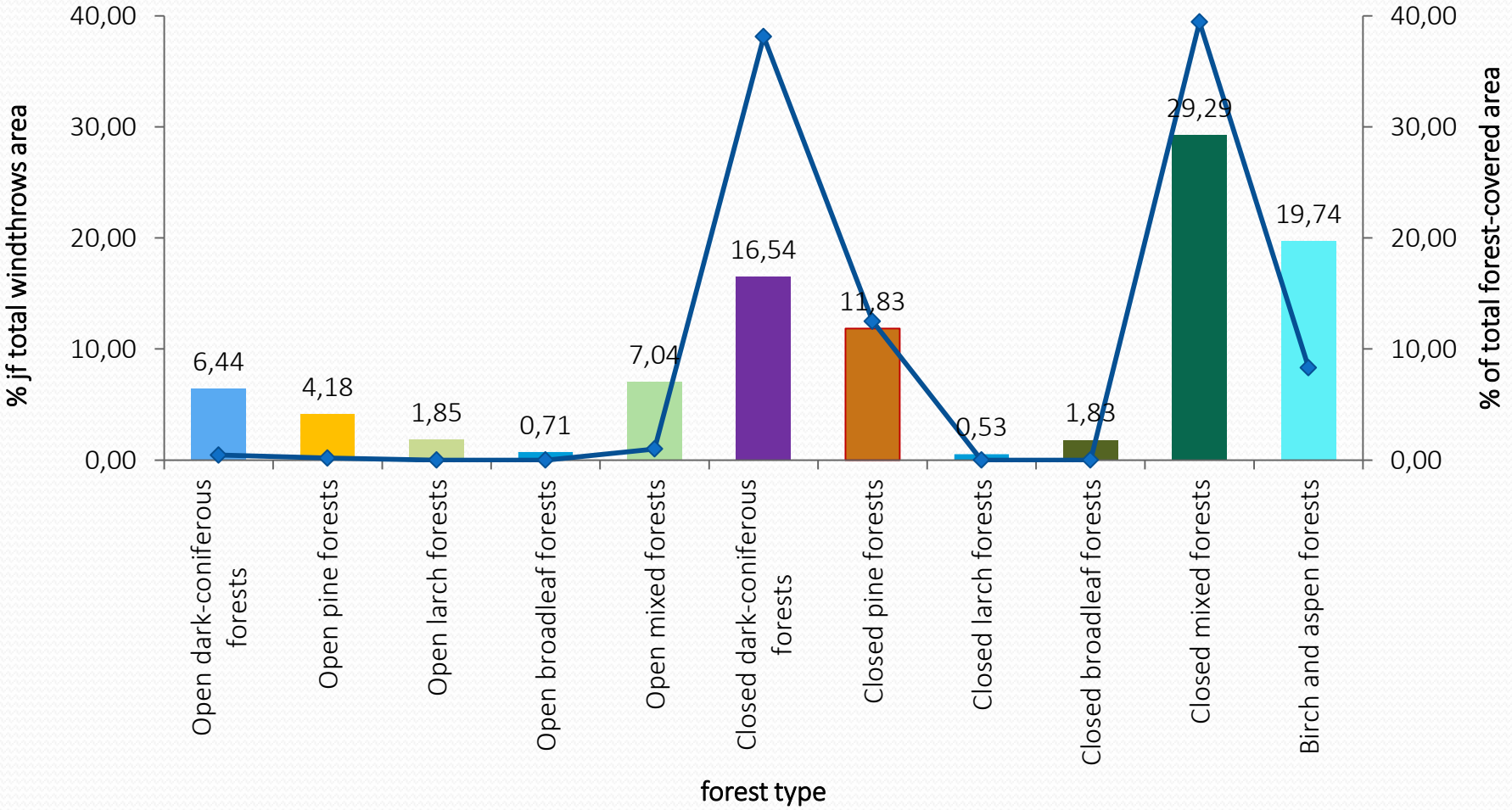
Interannual and monthly distribution, significance of trend

Parameter	Spearmen correlation/ significance level	Kendall correlation/ significance level
Windthrow area per year	0,24/0,18	0,18/0,15

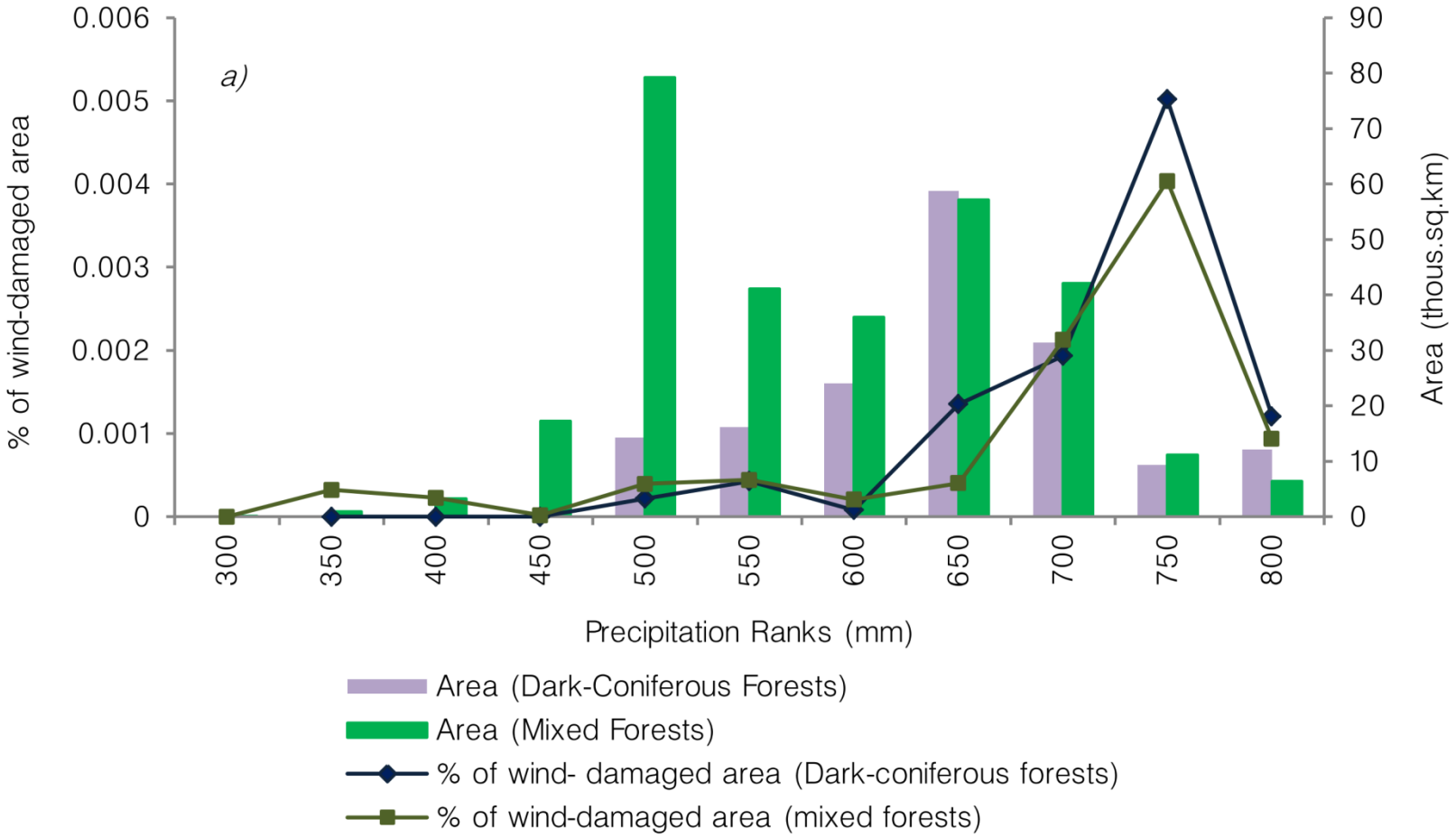




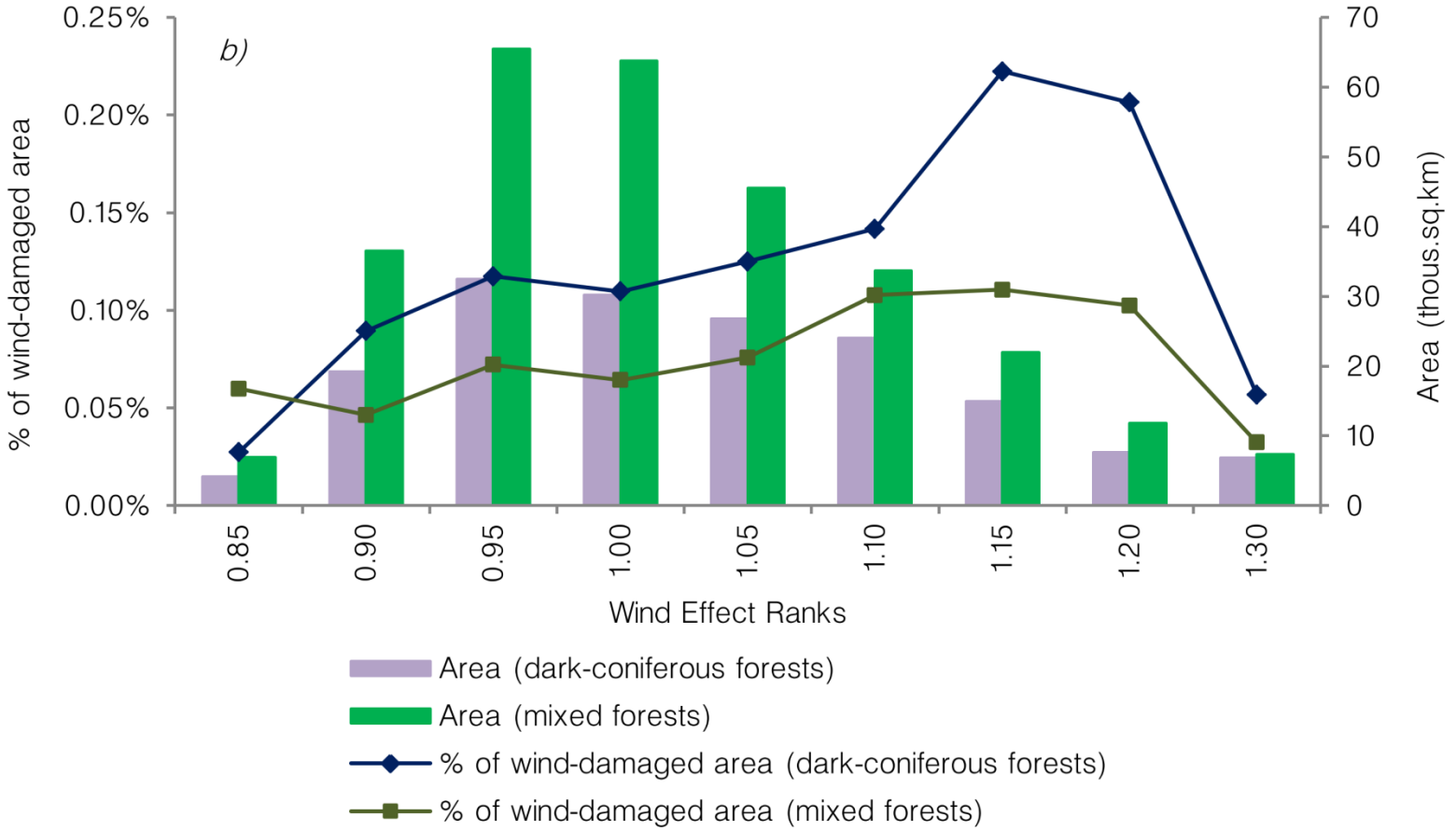
Distribution of windthrows area by prevailing forest types for 2001-2014, based on Russia's dominating forest types map (Bartalev et al., 2004)

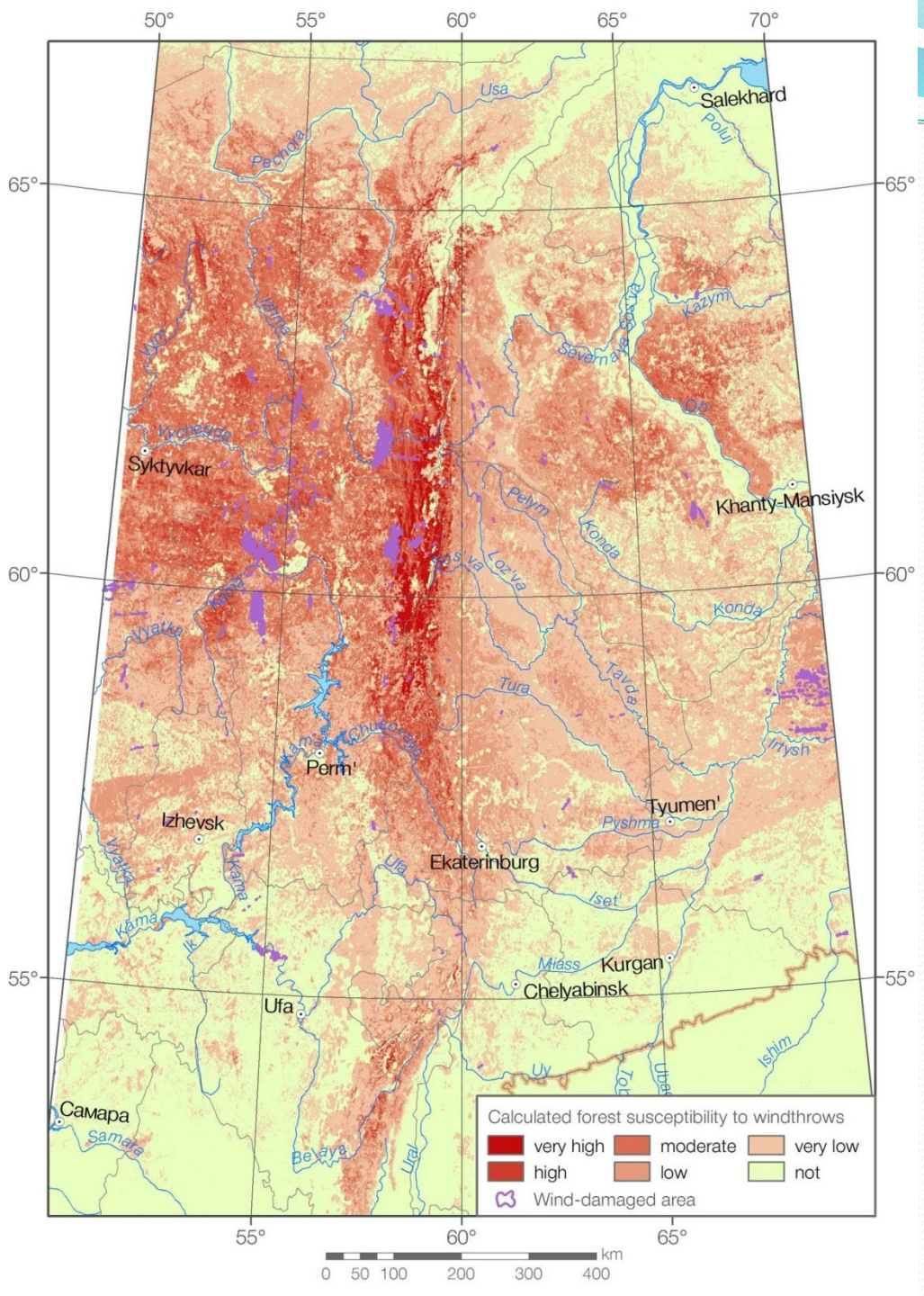


Percentage of windthrows area versus average annual precipitation (1971-2000, Worldclim 2.0 dataset).
Bars indicate the proportion of every variable rank in the study area, lines show the percentage of wind-damaged forested area



Percentage of wind-damaged area versus wind effect variable (calculated by DEM under the assumption of southwestern wind direction). Bars indicate the proportion of every variable rank in the study area, lines show the percentage of wind-damaged forested area





Calculated forest susceptibility to windthrows (estimated on the windthrows database for 2000-2014), taking into account forest type, annual precipitation and wind effect parameter

Web-GIS “Tornadoes in the forest zone of Russia” http://tornado.maps.psu.ru/

- A.N. Shikhov, Perm State University - searching of windthrows events, creation the database of tornadoes, determination of tornado dates
- A.V. Chernokulsky, Institute of Atmospheric Physics of RAS - determination of tornado intensity
- S.I. Perminov, Perm State University, Scanex RDS (after 2017) - development of the database on the PostgreSQL platform, web-GIS functionality and design
- I.O. Azhigov, Perm State University - searching of windthrows events an data updating for 2015-2018

Main content and functionality of the web-GIS

- Web-GIS present the database of tornado events in Russia, which caused forest damage, for 2000-2018.
- The database contains 312 tornado tracks, most of them were previously unknown and found by forest damage. Additional data (reanalysis maps, video) are presented for tornado events which dates are known.
- Landsat or Sentinel-2 images before/after of each tornado shows tornado-induced forest damage
- High-resolution satellite images from Here web map service
- “Tornado statistics” tool show the inter-annual and monthly distribution of tornado events, and also the distribution by direction movement, for entire Russia and for each region

Смерчи в лесной зоне России

О проекте

Идентифицирован 1 объект Очистить

Основные сведения

Дата	2008-08-30
Время (UTC)	13:00
Точность определения даты	1 час
Субъект РФ	Пермский край
Район	Краснокамский район
Населенный пункт	Дачный поселок Алешиха
Длина пути, км	6.0
Средняя ширина пути, м	154
Максимальная ширина пути, м	250
Направление	WSW-ENE
Расчетная интенсивность (F-Scale)	F1
Дополнительная информация	Смерч прошел через юго-западную часть дачного пос. Алешиха. Повреждены десятки строений, ранен 1 чел.
Внешняя ссылка	Подробнее

Видеоматериалы

Карты реанализа

Геопотенциал H500

Индекс смерчеопасности SWEAT

Температура T850

Фрагменты космоснимков

Снимки Landsat: до после

Все регионы России

приблизьте карту для отображения снимков сверхвысокого разрешения

Случаи смерчей за период с 2000 по 2017 гг.

2000 2002 2004 2006 2008 2010 2012 2014 2016

Расчетная интенсивность (F-Scale)

F1
F2
F3
нет данных

ГИС-Центр ПГНИУ

58.363°N, 57.686°E | M 1:10'000'000

Смерчи в лесной зоне России

О проекте

Идентифицирован 1 объект | Очистить

Основные сведения

Дата	2009-06-07
Время (UTC)	13:00
Точность определения даты	1 час
Субъект РФ	Республика Коми
Район	Усть-Куломский район
Населенный пункт	10 км от с. Канава
Длина пути, км	17.5
Средняя ширина пути, м	267
Максимальная ширина пути, м	600
Направление	SSW-NNE
Расчетная интенсивность (F-Scale)	F2
Дополнительная информация	Смерч прошел в малонаселенной местности. Разрушений инфраструктуры и пострадавших среди населения нет. Всего в этот день отмечено 13 смерчей в Пермском крае и Республике Коми
Внешняя ссылка	Подробнее

Карты реанализа

Геопотенциал H500
Индекс смерчеопасности SWEAT
Температура T850

Фрагменты космоснимков

✓ Снимки Landsat: до после

Все регионы России

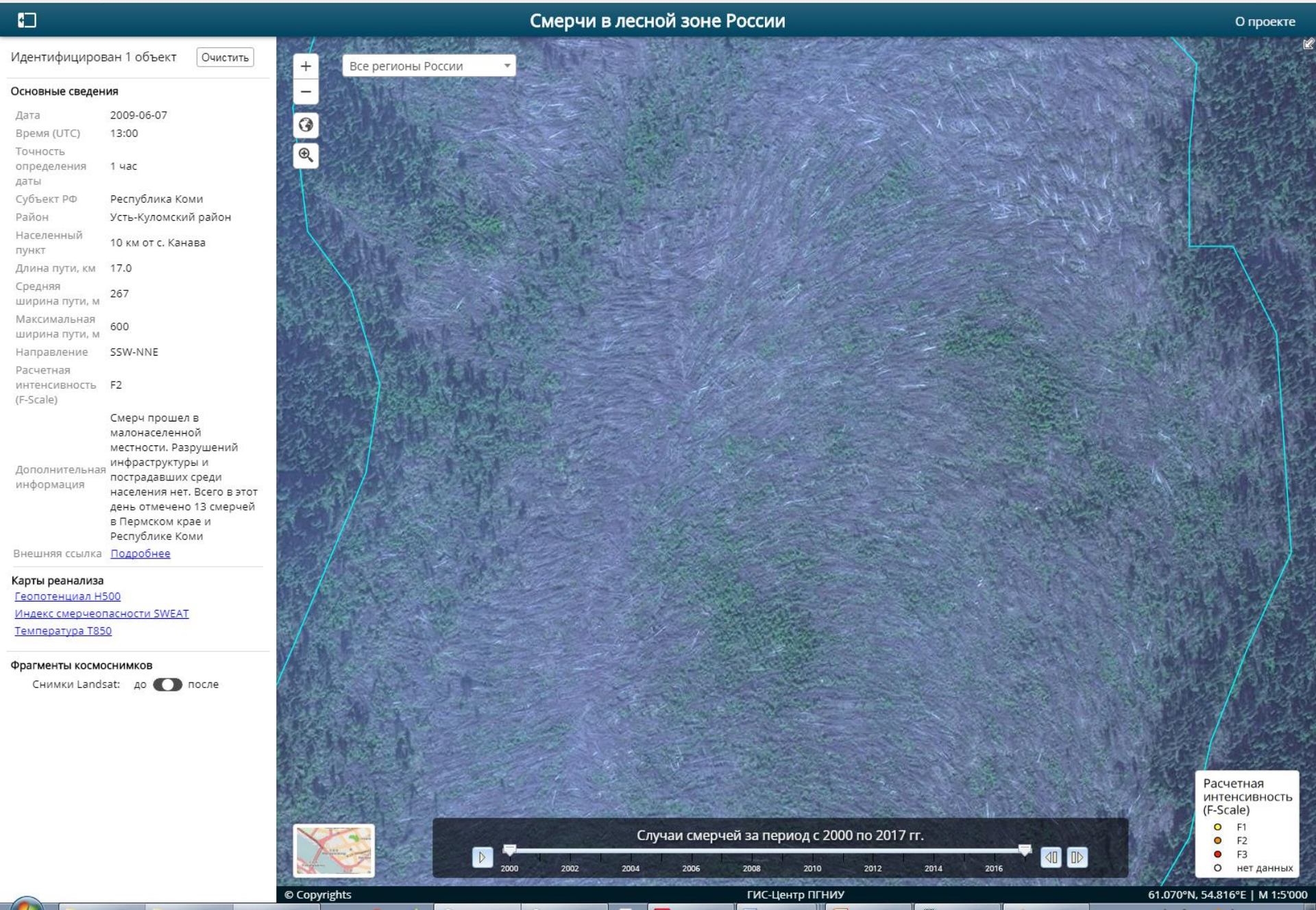
приблизьте карту для отображения снимков сверхвысокого разрешения

Случаи смерчей за период с 2000 по 2017 гг.

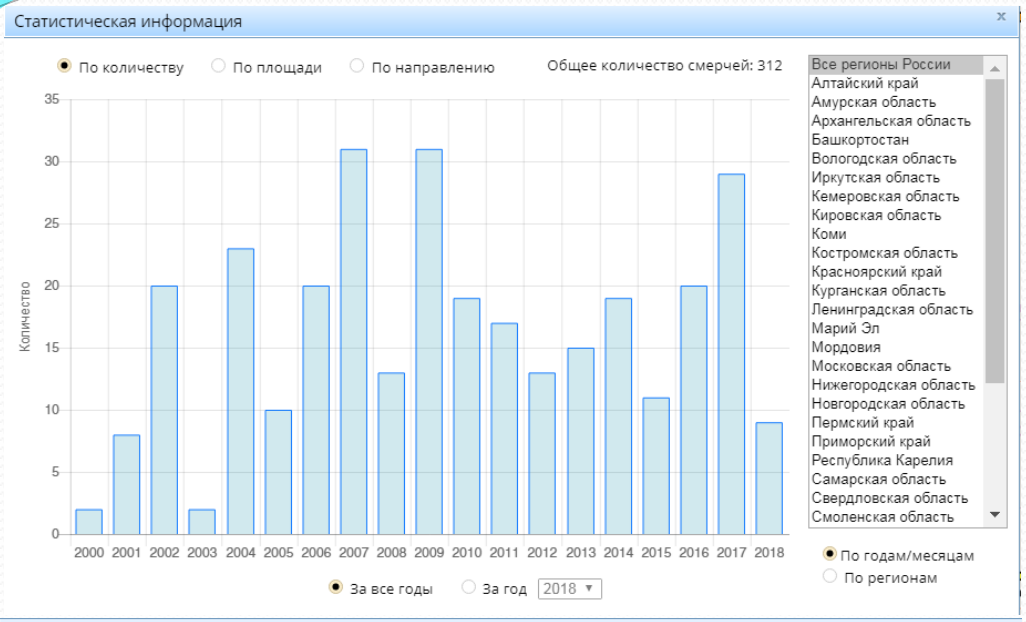
2000 2002 2004 2006 2008 2010 2012 2014 2016

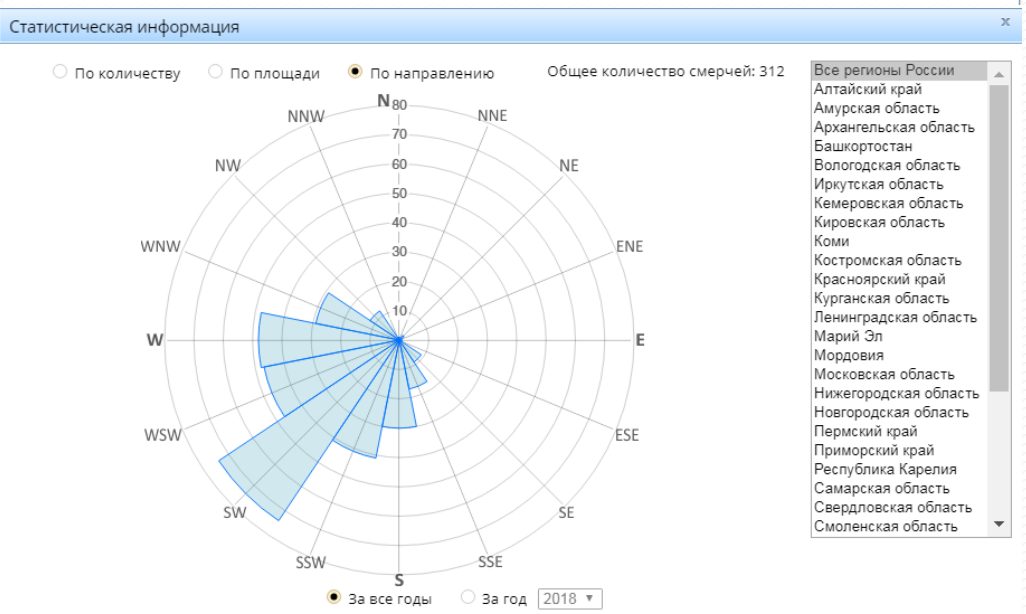
Расчетная интенсивность (F-Scale)
F1
F2
F3
нет данных

ГИС-Центр ПГНИУ
61.266°N, 55.198°E | M 1:300'000


Смерчи в лесной зоне России
О проекте
Идентифицирован 1 объект
Очистить
Основные сведения
Дата 2009-06-07
Время (UTC) 13:00
Точность определения даты 1 час
Субъект РФ Республика Коми
Район Усть-Куломский район
Населенный пункт 10 км от с. Канава
Длина пути, км 17.0
Средняя ширина пути, м 267
Максимальная ширина пути, м 600
Направление SSW-NNE
Расчетная интенсивность (F-Scale) F2
Дополнительная информация Смерч прошел в малонаселенной местности. Разрушений инфраструктуры и пострадавших среди населения нет. Всего в этот день отмечено 13 смерчей в Пермском крае и Республике Коми
Внешняя ссылка Подробнее
Карты реанализа
Геопотенциал H500
Индекс смерчеопасности SWEAT
Температура T850
Фрагменты космоснимков
Снимки Landsat: до после
Все регионы России
Случаи смерчей за период с 2000 по 2017 гг.
2000 2002 2004 2006 2008 2010 2012 2014 2016
Расчетная интенсивность (F-Scale)
F1
F2
F3
нет данных
© Copyrights
ГИС-Центр ПГНИУ
61.070°N, 54.816°E | M 1:5'000

“Tornado statistics” tool





- 312 tornado events (in total)
- Highest number of tornadoes in 2007, 2009 (>30 tornadoes per year)
- Extreme tornado outbreaks (> 10 tornadoes per day) 23 June 2007 (Northern Ural), 7 June 2009 (Perm region and Komi Republic) and 2 Aug 2017 (Tver’ region)

Main results and planned studies

- A new database on windthrows caused by squalls, tornadoes and heavy snowfall is created for the North-East of European Russia
- The most catastrophic windthrows are occurred in 1993, 1995, 2009 an 2012. Some catastrophic events caused ~ 50% of total forest damage.
- A statistically significant long term trend of the windthrows area is not found
- Forest susceptibility to windthrows is related to forest species composition, yearly precipitations and wind exposition.
- **Planned studies**
- Create the windthrows database for entire European Russia and Ural from 1985 to present
- Estimate the long-term trend of windthrows damage caused by squalls and tornadoes
- Perform a more detailed analysis of forest susceptibility to windthrows
- A new windthrows database will be published on the web-GIS “windthrows in the forest zone of Russia” (created on the basis of existing web-GIS)

Publications

- Shikhov A.N., Perminov S.I., Kiseleva E.S. Assessment of boreal forests vulnerability to fire- and wind-induced disturbances from long-term series of satellite observations within the Urals region // Current Problems of the Earth remote sensing from Space. 2017. Vol. 14(4), pp. 87–102. URL: http://jr.rse.cosmos.ru/article.aspx?id=1677& (in Russian)
- Shikhov A.N., Zaripov A.V. Long-term dynamics of fire- and wind-induced forest losses in the north-east of European Russia with satellite data // Current Problems of the Earth remote sensing from Space. 2018 (Accepted in print)
- Shikhov A.N., Chernokulsky A.V. (2018) A satellite-derived climatology of unreported tornadoes in forested regions of northeast Europe // Remote Sensing of Environment. Vol. 204. PP. 553–567. URL: https://www.sciencedirect.com/science/article/pii/S0034425717304662

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