Assessment of a Forest-fire Danger Index for Russia Using NOAA Information

Anatoly I. Sukhinin[1], Douglas J. McRae[2], and Eugene I. Ponomarev[1]

presented by

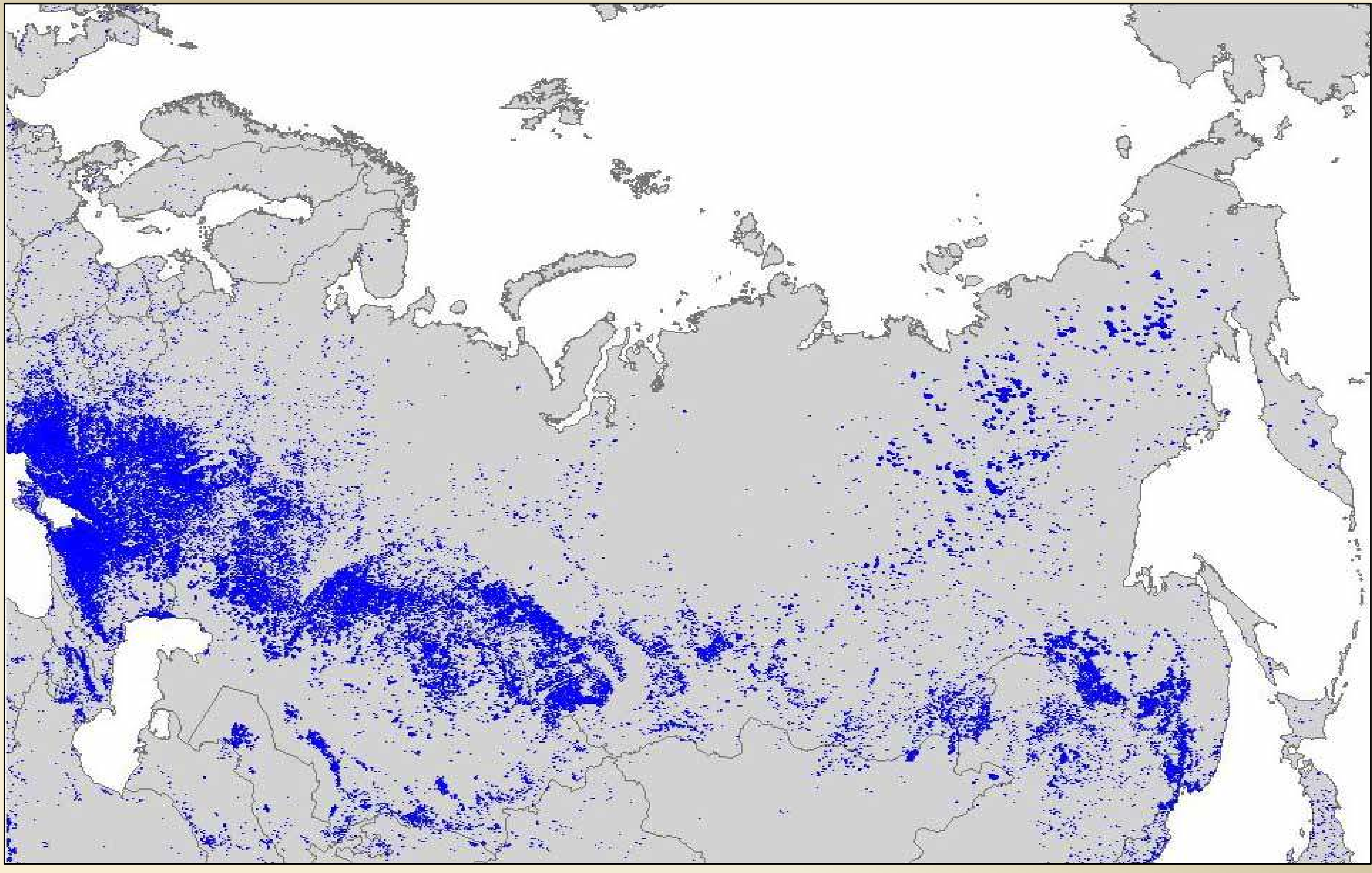
Ivan Csiszar[3]

[1] Sukhachev Institute of Forest SB RAS, Laboratory Of Forest Fire Remote Sensing, Krasnoyarsk, Russia, E-mail: boss@ksc.krasn.ru

[2] Canadian Forest Service, Great Lakes Forest Centre, Sault Ste. Marie, Ontario, Canada

[3] University of Maryland Department of Geography College Park, MD USA

Fire disturbance in Northern Eurasia

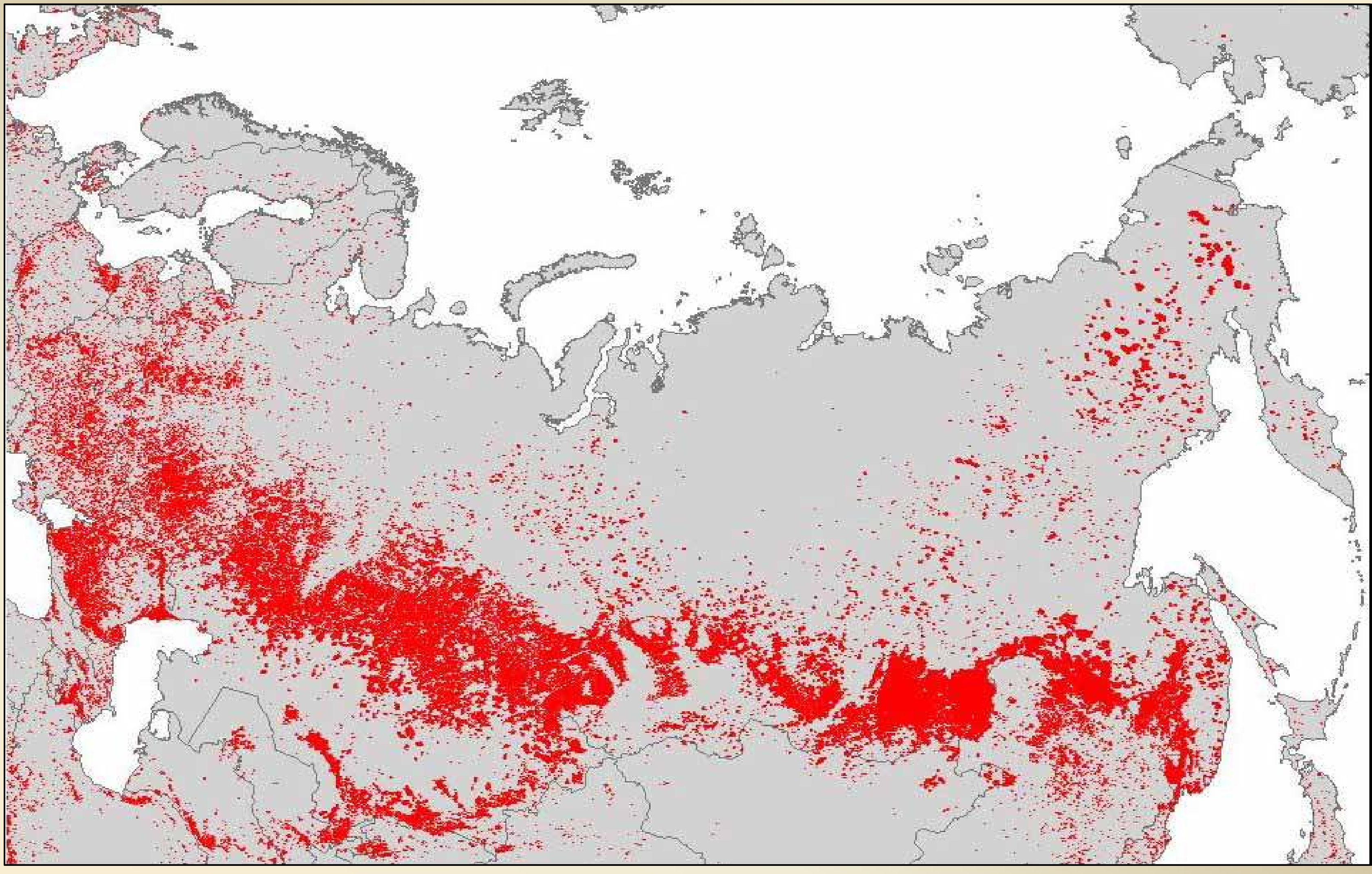


MODIS active fire detections: ● **2001 (Terra)**

Fire disturbance in Northern Eurasia

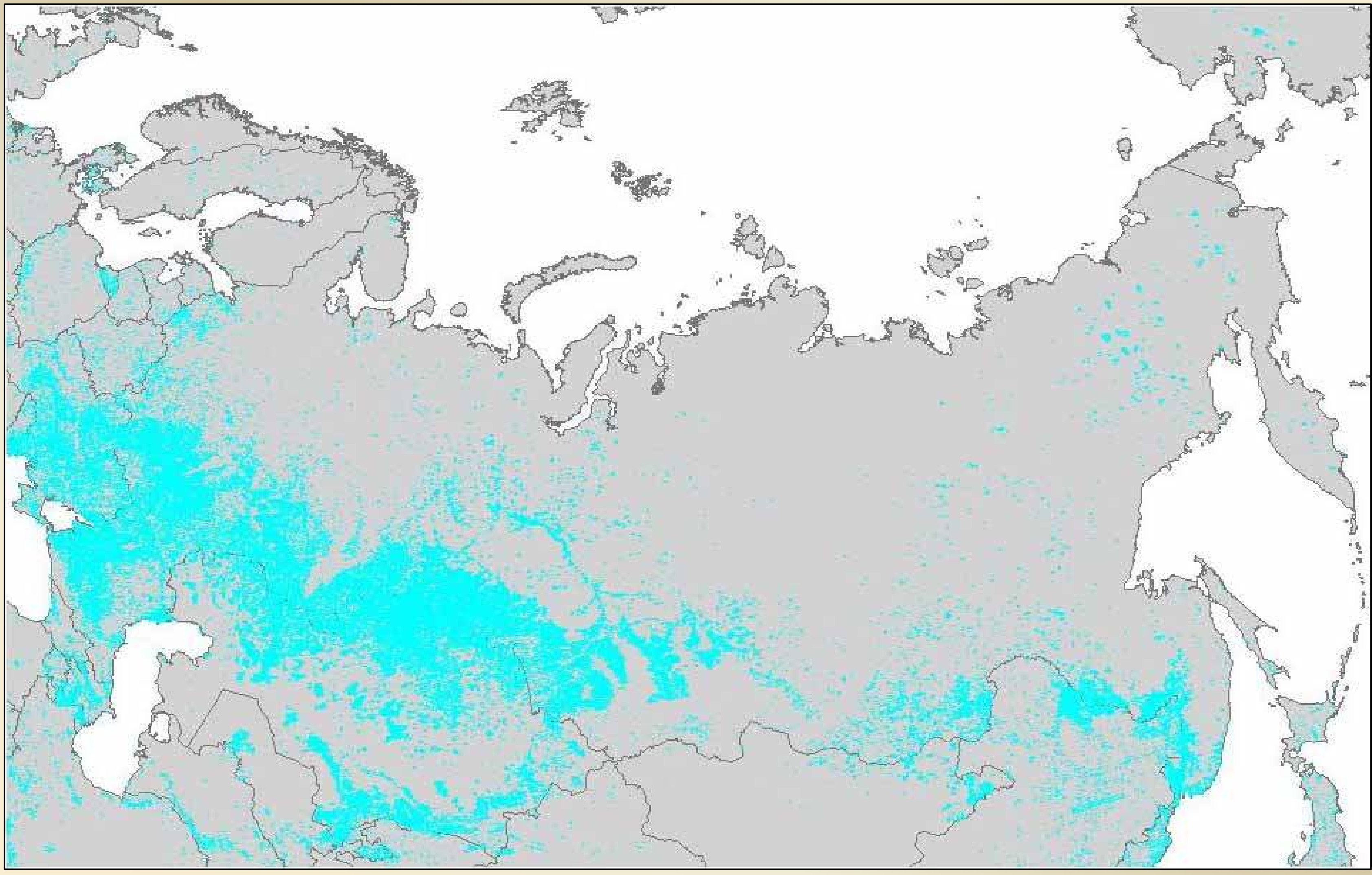
MODIS active fire detections: ● **2002 (Terra)**

Fire disturbance in Northern Eurasia



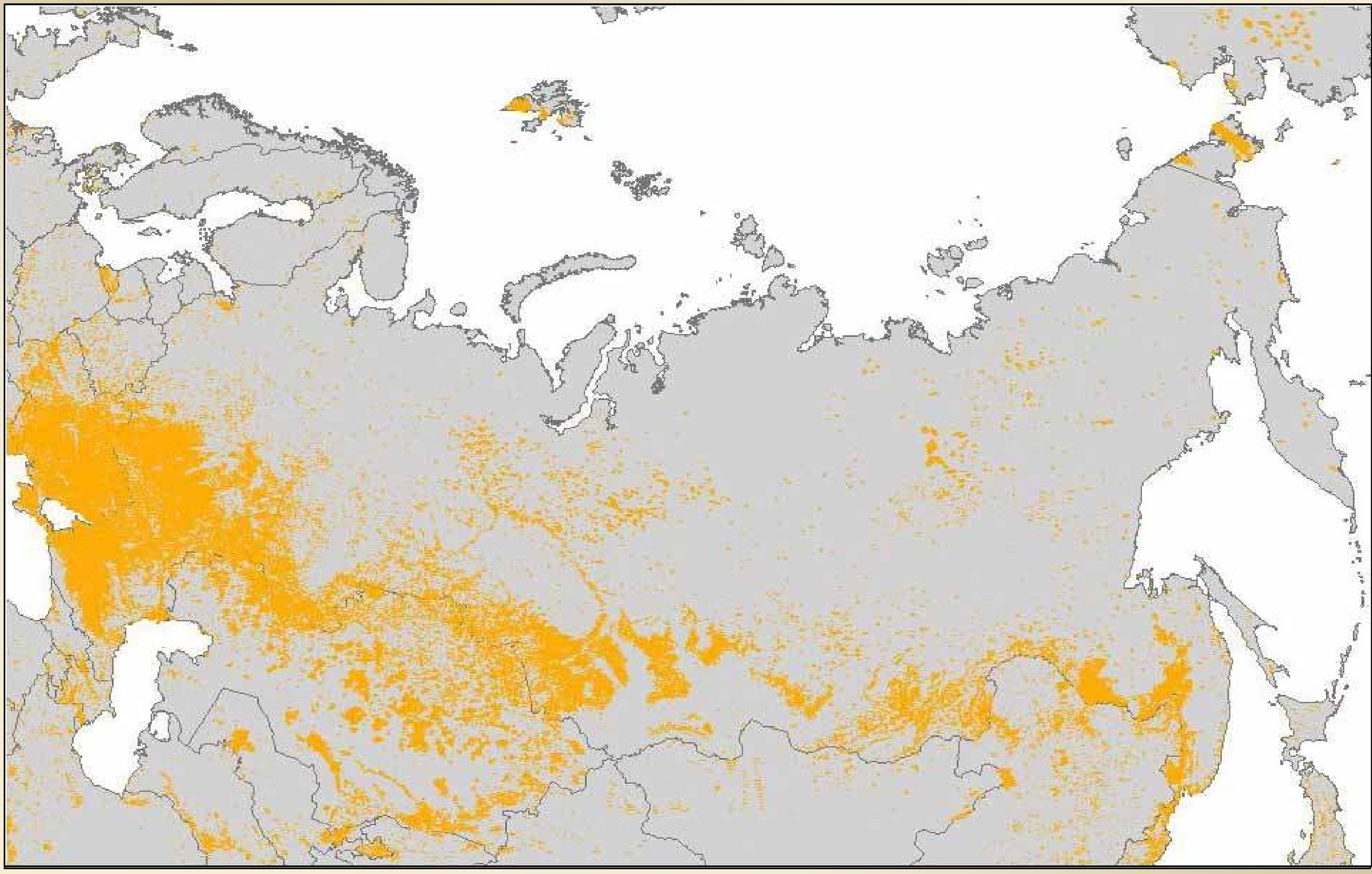
MODIS active fire detections: ● **2003 (Terra and Aqua)**

Fire disturbance in Northern Eurasia



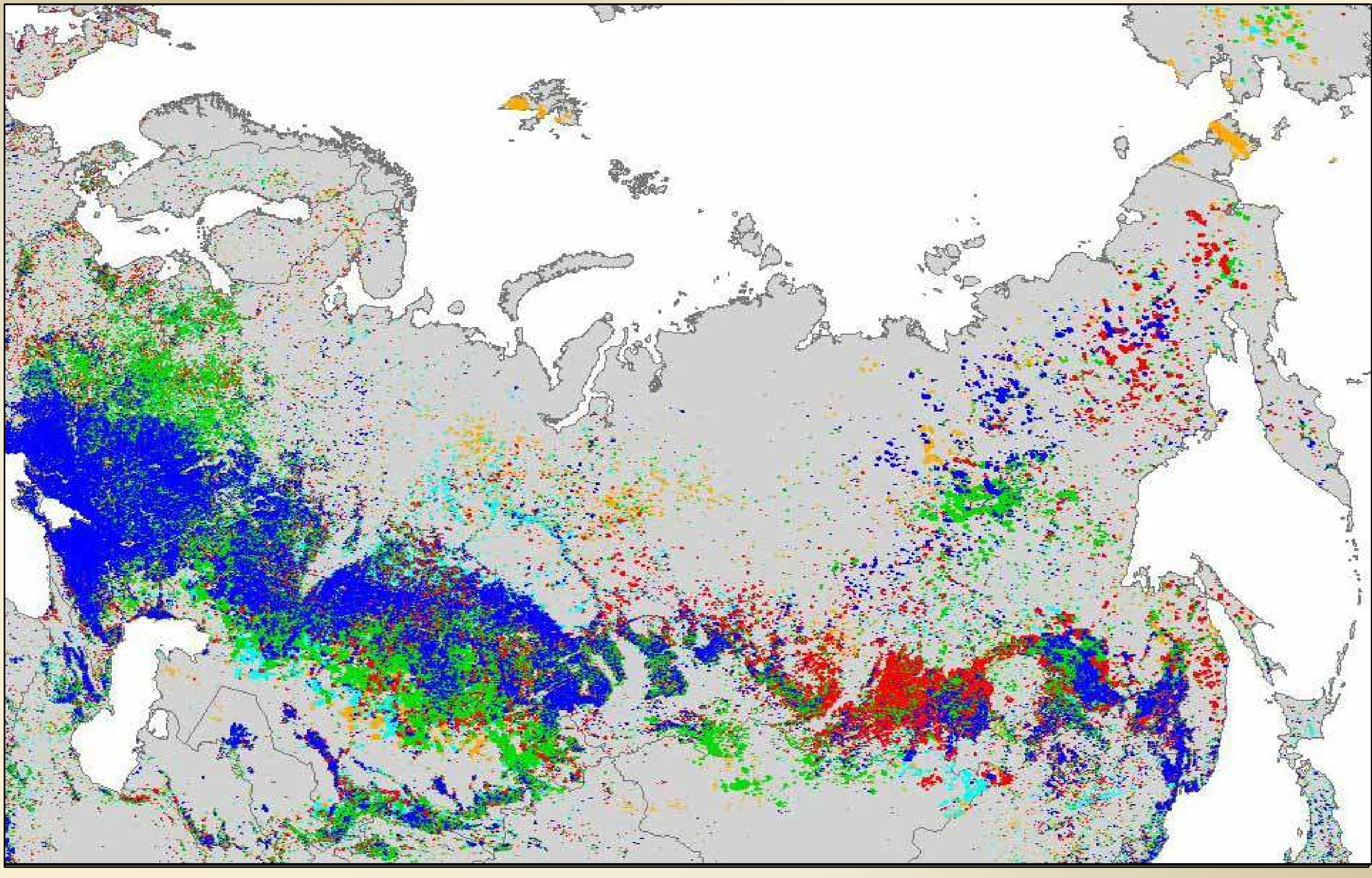
MODIS active fire detections: ○ **2004 (Terra and Aqua)**

Fire disturbance in Northern Eurasia



MODIS active fire detections: ● 2005 (Terra and Aqua)

Fire disturbance in Northern Eurasia



MODIS active fire detections: ● **2001** ● **2002** ● **2003** ● **2004** ● **2005**

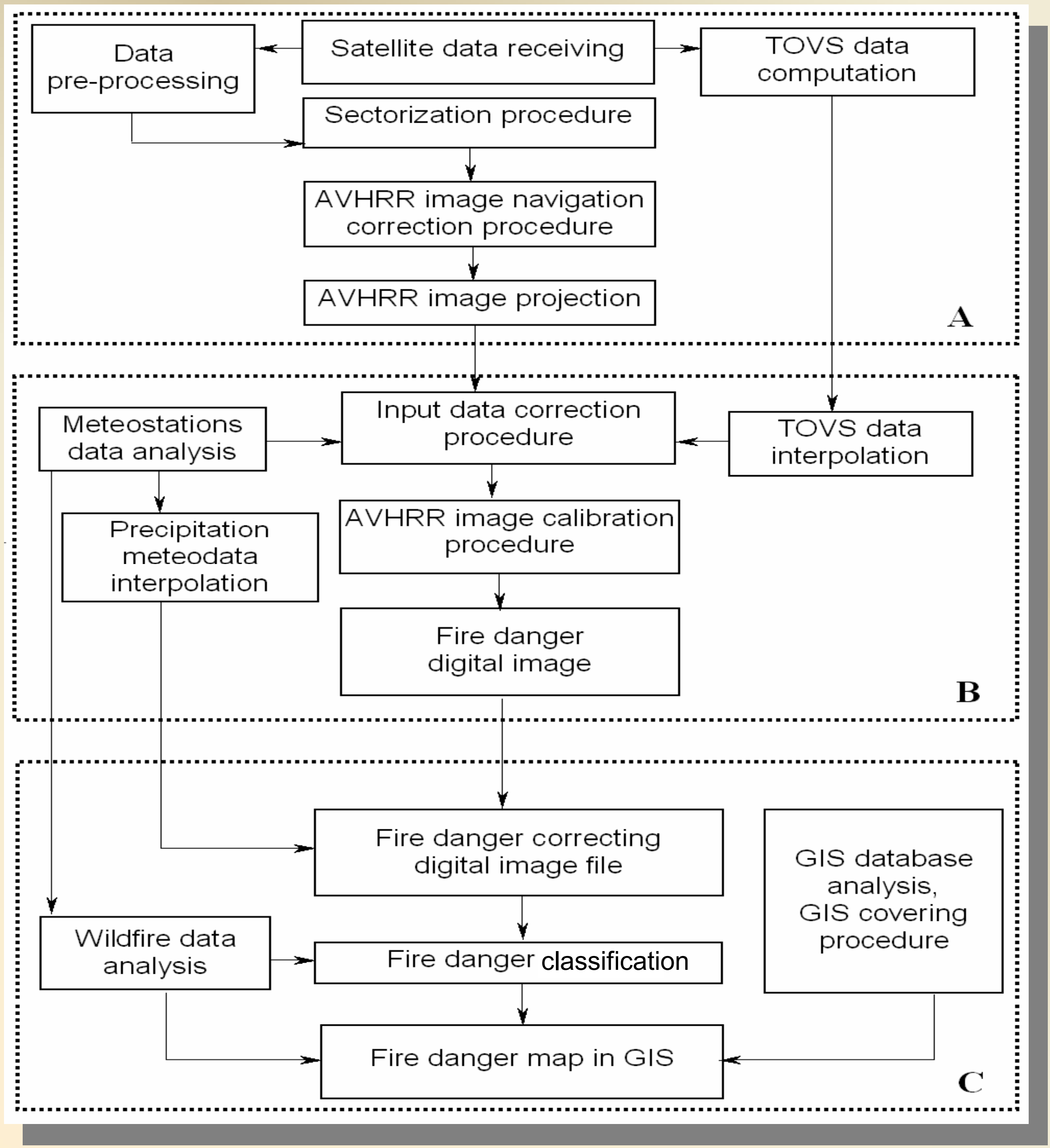
Introduction

- Russia encompasses large remote forested regions
- No dense network of local weather stations needed to calculate fire danger
- Remote sensing using satellite data can provide reasonable estimates of fire danger across Russia
- An algorithm has been developed that can assess current fire danger
- Ambient weather conditions derived from remote sensing data obtained from NOAA satellites (AVHRR and TOVS)
- Surface temperature, dew point and precipitation

Satellite data and preprocessing

- NOAA/AVHRR: imager
  - spatial resolution of 1.1 km with a wide swath of about 2700 km
  - data is acquired for the same area twice a day by the same satellite
  - radiative surface temperatures, vegetation indices, etc.
- NOAA/TOVS: vertical sounding system
  - collects data on characteristics for the near-surface atmospheric layer
    - e.g., dew point temperature, wind parameters, pressure distribution, etc.
- Preprocessing: three stages
  - acquisition and recording of the satellite signal
  - radiometric data calibration, sectorization (i.e., selection of a specific scene and AVHRR channel combination)
  - geographical correction of imagery and cartographic projection
- Fire-danger index involves three AVHRR channels
  - channels 1 and 2 - surface albedo
    - also cloud screening and detection of water surfaces
  - channel 5 - surface temperature
  - correction based on precipitation information obtained from local weather stations

Processing scheme

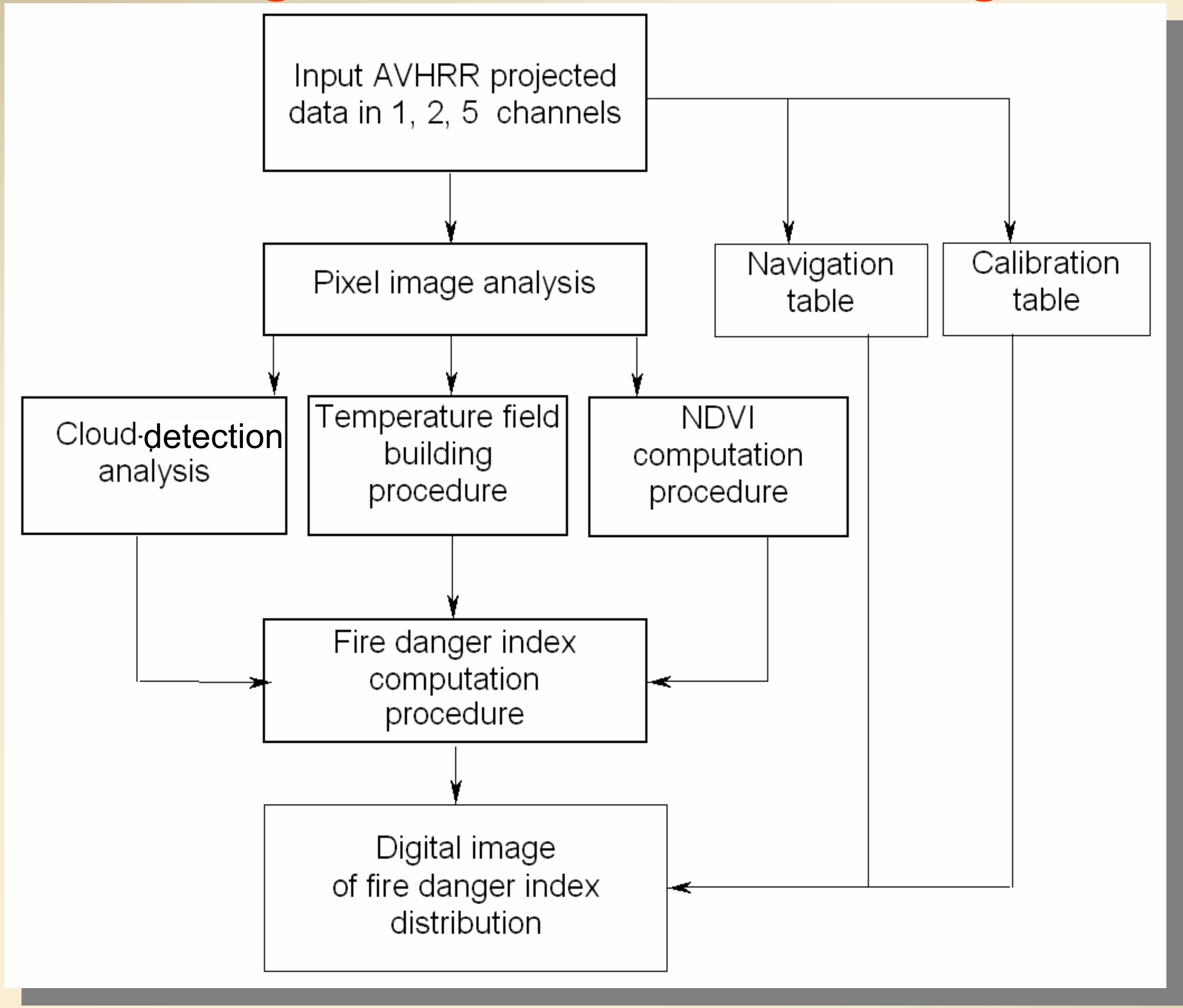


A – Preprocessing of satellite data

B – Software development

C – GIS mapping

NOAA-satellite data processing for determining the forest Fire Danger Index



Estimation of fire danger index

- Nesterov's equation (slightly modified to improve its performance)

$$\Gamma_{ij} = \sum_i a_i \xi_i \sum_j t_{ij} (t_{ij} - \tau_{ij})$$

$$a = \left(\frac{A_3 - A_1}{A_3 + A_1} \cdot \frac{A_2 + A_1}{A_2 - A_1} \right)_{NOAA-16}$$

i: scene
j: day

- Γ_{ij} :fire danger index
- τ : dew point temperature (°C) from TOVS data
- t : radiative surface temperature (°C) from AVHRR data
- ξ : precipitation coefficient obtained from TOVS/GIS weather data
- A_n: albedos for AVHRR Channels 1, 2 and 3 from NOAA-16

Processing software

- Projection of pixel data onto a given cartographic projection
  - daily updated fire-danger index maps
- Radiometric parameters for the underlying surface from remote-sensing instead of actual meteorological parameters to estimate atmospheric near-surface layer parameters
  - high correlation between substantiates the development of a fire-danger index using remote sensing
- NOAA-16/AVHRR channel 3 data
  - correction factor for vegetation index (AVHRR Channels 1 and 2 data)
  - quantitative estimation of surface moisture
- Cloud obscuration: NOAA/TOVS instrument data
  - microwave TOVS data allow for the restoration of atmospheric moisture and temperature parameters for overcast regions

Processing software (cont)

- Interpolation: piecewise-linear approximation method
  - consists of representing the surface defined by a function with a piecewise-linear surface consisting of triangle elements
  - net of non-intersecting triangles is created over a plane *(x, y)*, where the projection of each point of space in the plane belongs to a particular triangle
  - the value of any function *f(x, y)* is interpolated using the piecewise-linear function given Delaunay's triangulation node values
- Linear extrapolation using the three nearest data points (i.e., the vertices of a triangle containing the given point) enables to restore a parameter value at any point using the TOVS data
- High correlation between NOAA measurements and temperature data recorded at the on-ground weather stations (r = 0.7)
  - mean bias 4-6°C
- Corrected TOVS data were used in the estimation of the fire-danger index

GIS mapping

- ARC/INFO 3.4.2 and ArcView 3.2 software packages
- Classes of fire danger are selected according to the range of actual fire-danger index values
- Further processing using GIS technology could combine the fire-danger maps produced here with forest fuel information
- Maps of potential levels of fire behavior and fuel consumption.

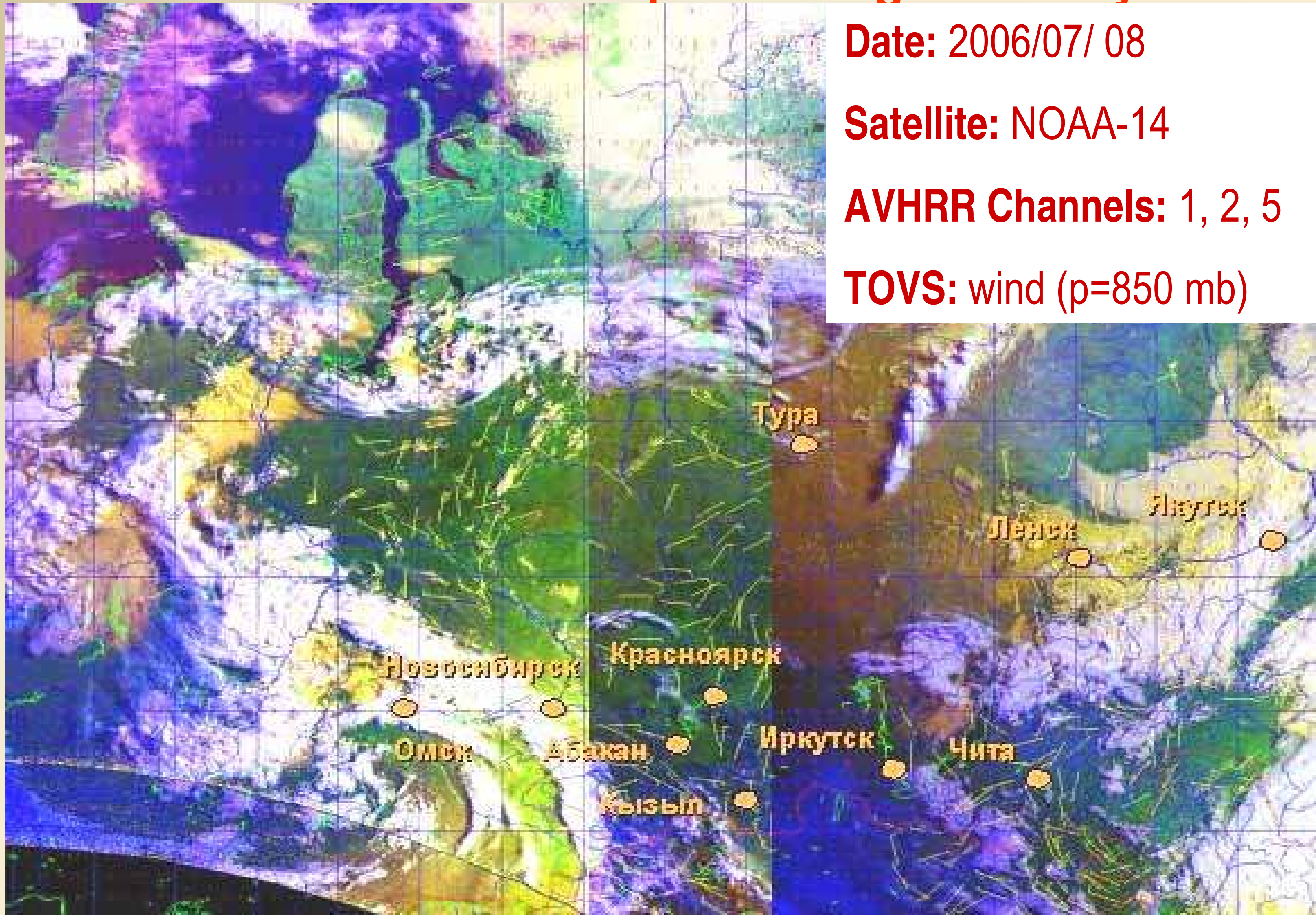
Raw NOAA Satellite data and weather data used in GIS weather database processing and analyses

Date: 2006/07/ 08

Satellite: NOAA-14

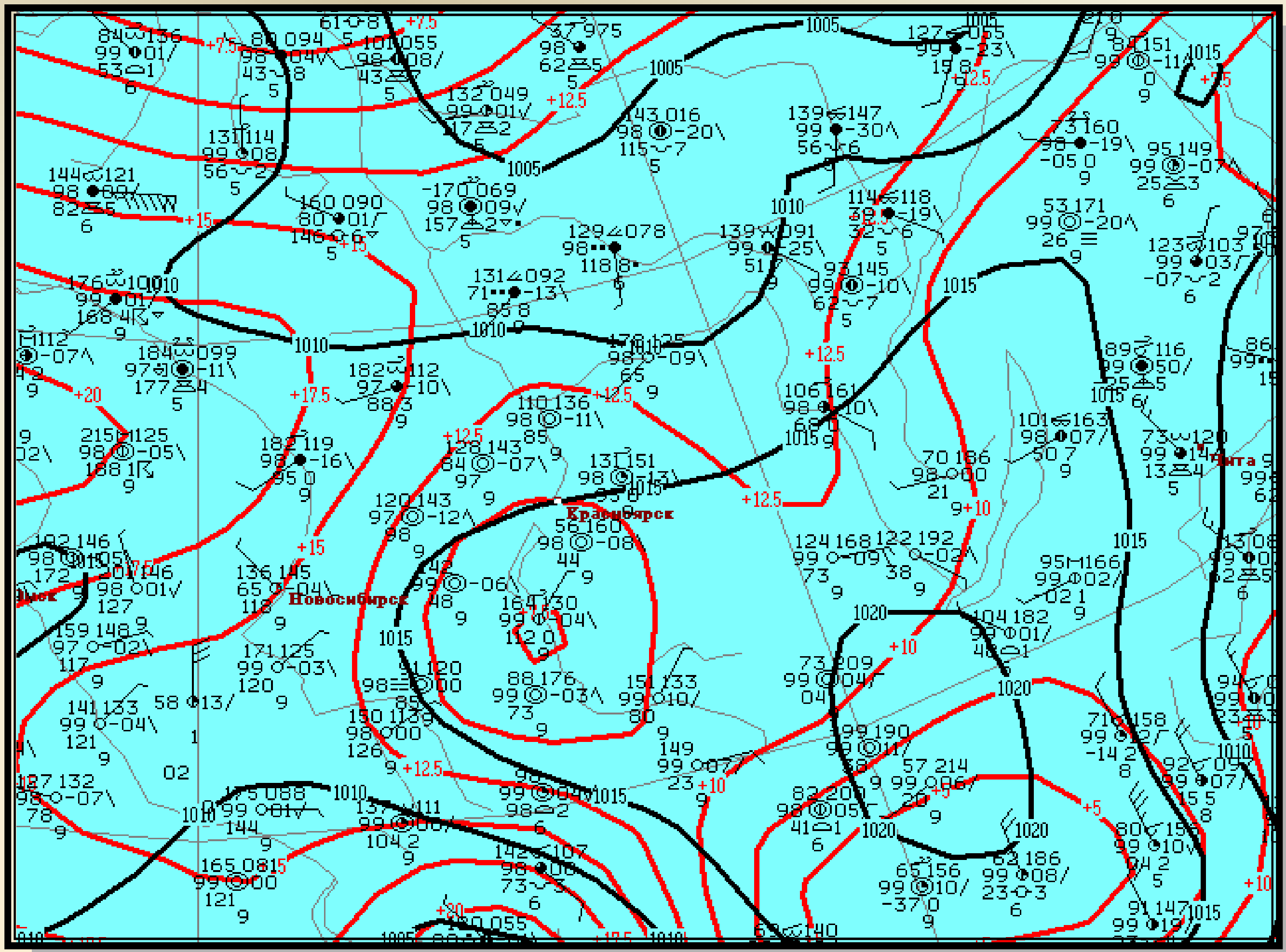
AVHRR Channels: 1, 2, 5

TOVS: wind (p=850 mb)

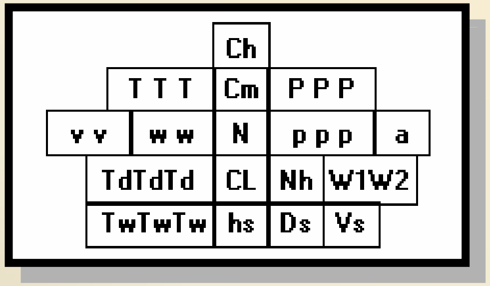


Visible and near-infrared channels (1, 2) of AVHRR: detection of clouds and water body surfaces. Channel 5: the temperature field (thermal range). TOVS data: humidity, wind speed and direction.

Map of pressure, temperature, and cloudiness



Pattern of data layout:



Cloudiness: CL – lower layer

Cm – medium layer

Ch – higher layer

hs - Lower layer cloudiness height

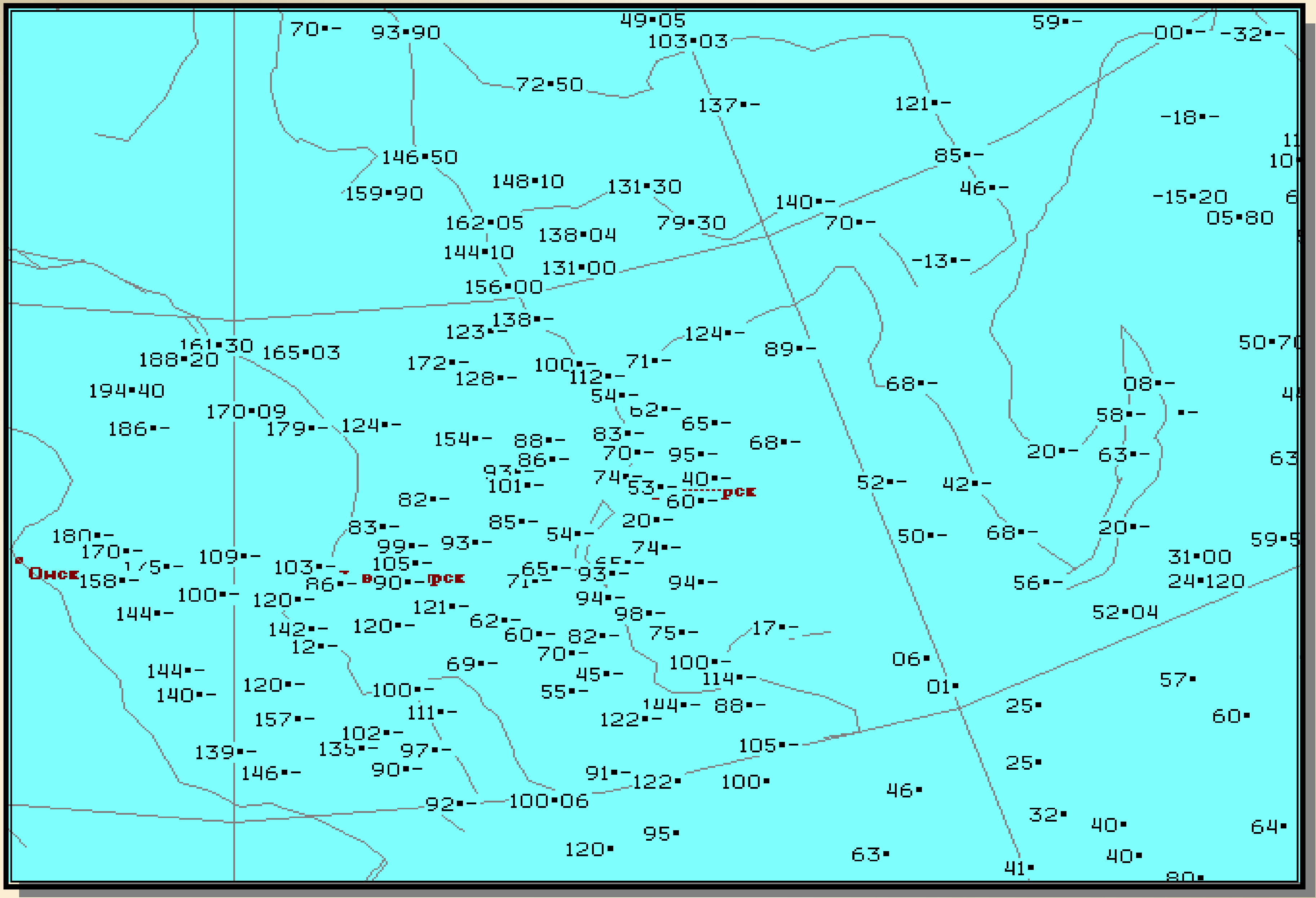
TTT – air temperature

TdTdTd – dew point temperature

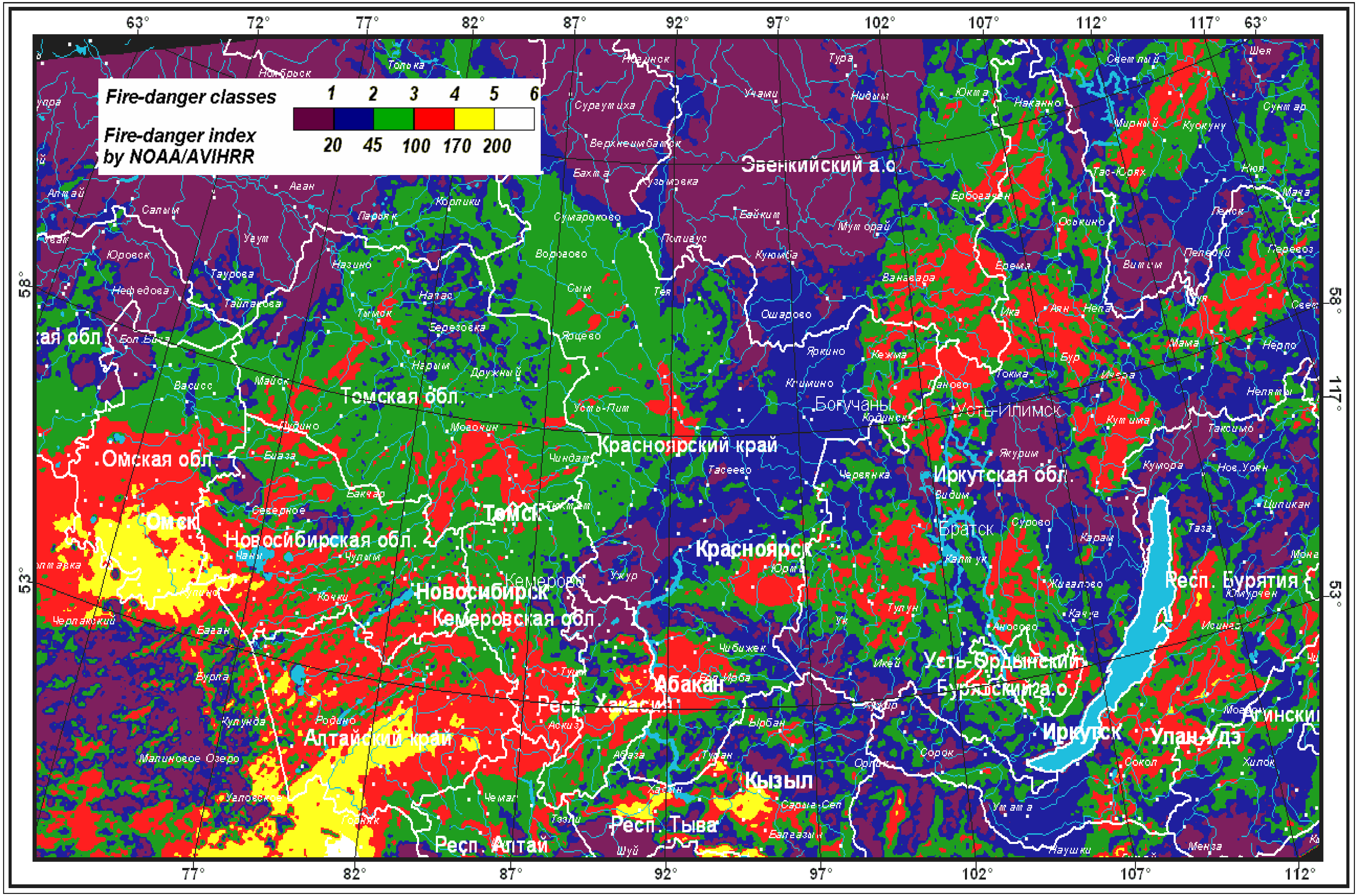
ww – weather phenomena

PPP – pressure at the sea level

Map of precipitation

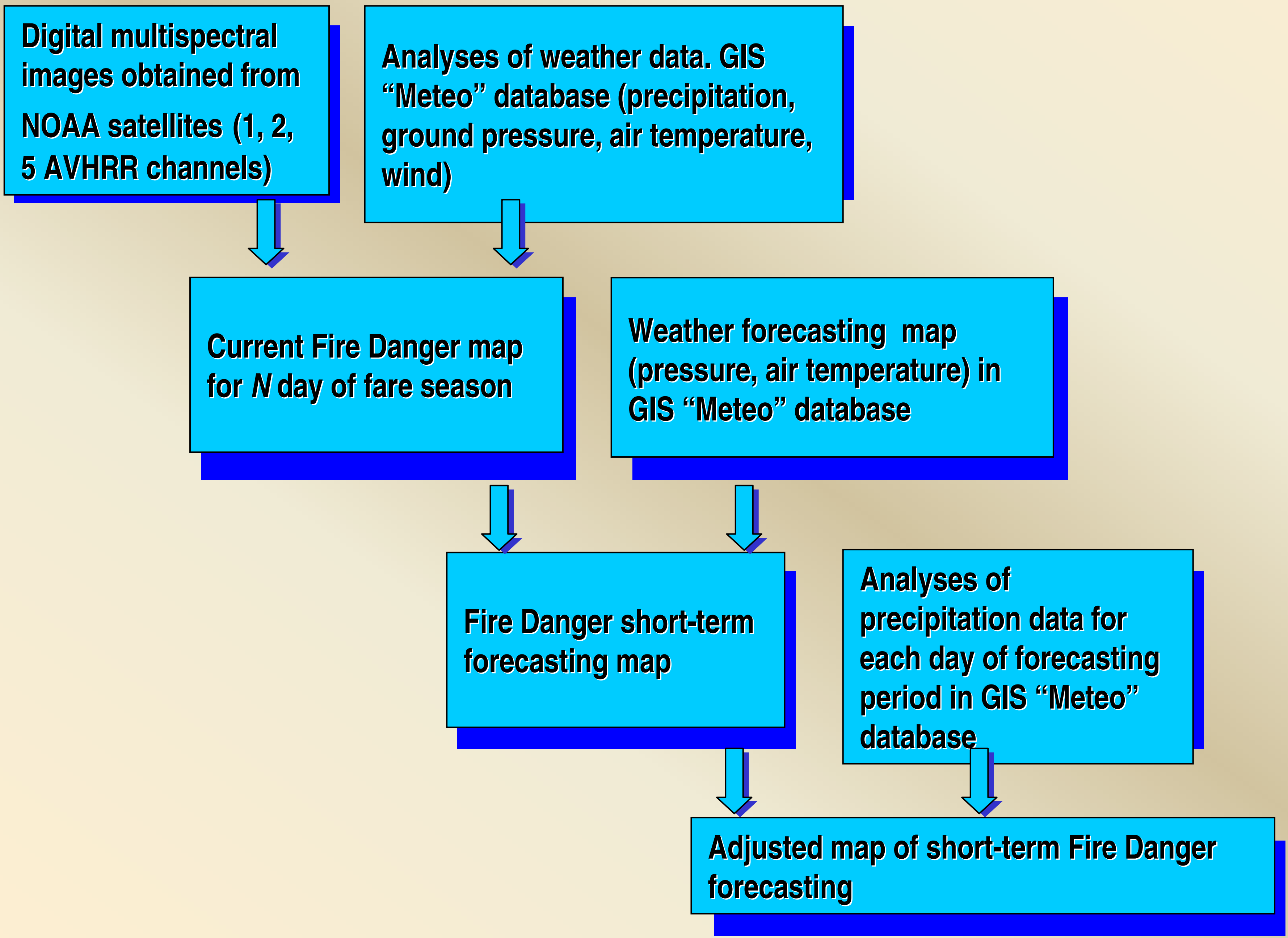


Fire Danger classes as estimated by NOAA-14 data for August 8, 2007



Fire danger classes are based on those used by the Russian Fire Service

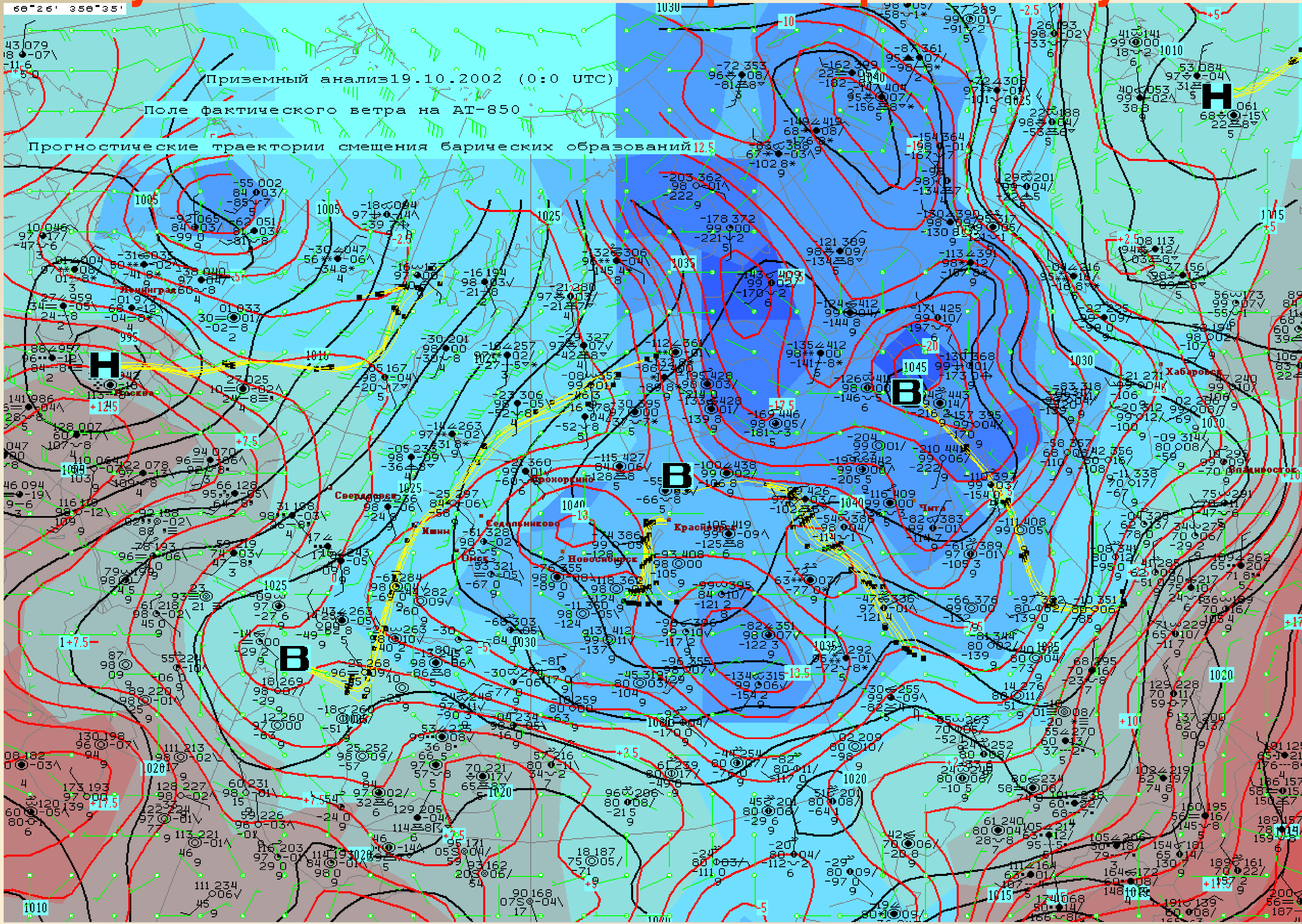
Method of fire weather danger prediction on the basis of satellite data and GIS “Meteo” database



Fire danger forecasts

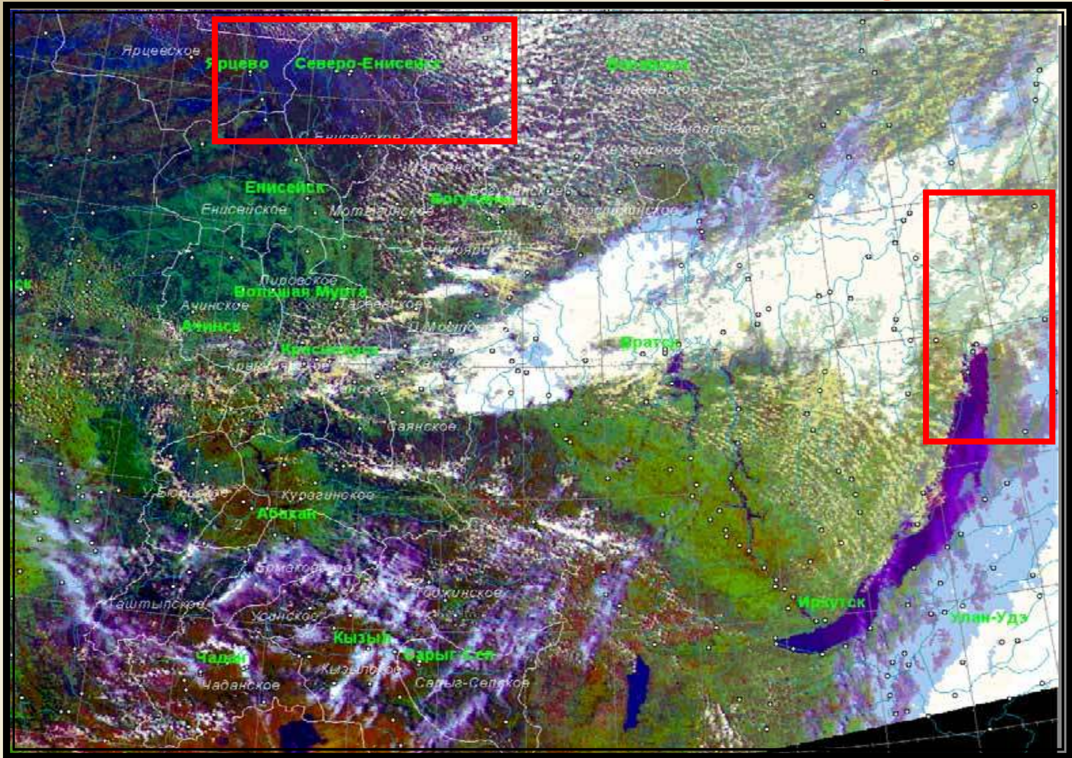
- Predict the occurrences and fire behavior of any future wildfires
- Short-term meteorological forecasts
  - short-term prognoses of air temperature and pressure over the periods of 12 to 168 hours are available as a part of the world database GIS “Meteo”
- Prediction map showing the upper limits of fire danger for Russia (i.e. the maximum values of fire weather danger in the absence of precipitation) over the next 1 to 7 days
- On a daily basis, the prediction maps are updated using actual precipitation recorded at on-ground weather stations.

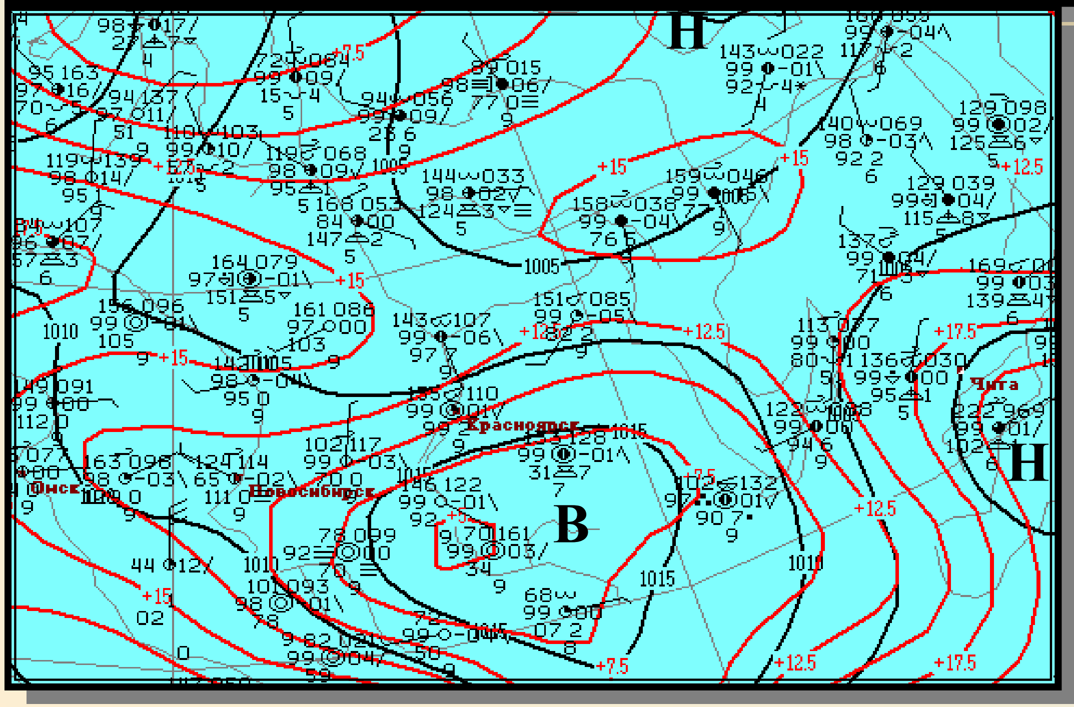
5- days forecast of main atmospheric pressure systems

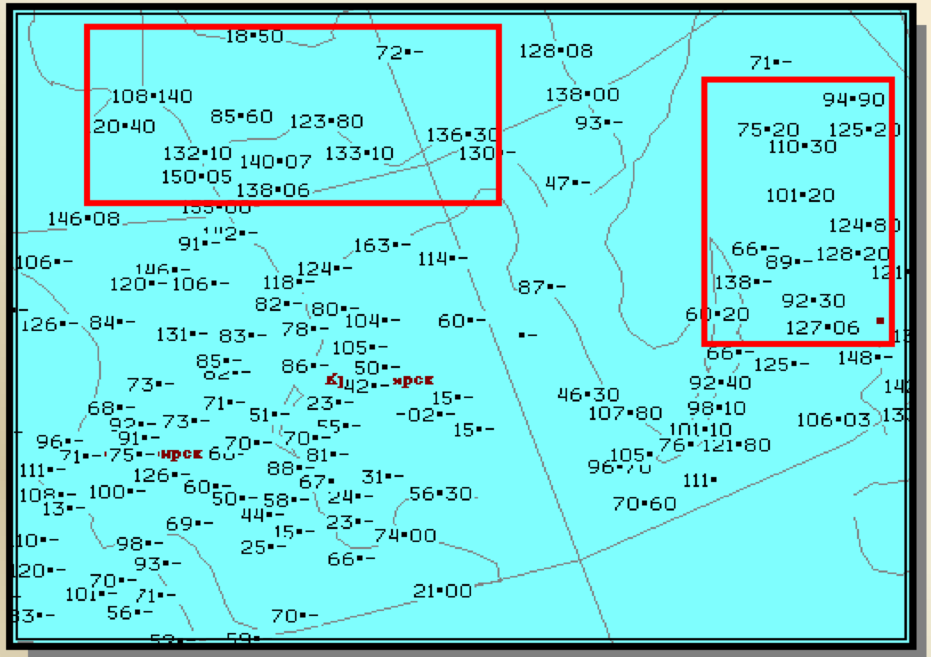


“B”: high; “H”: low

Actual state during the forecasted period



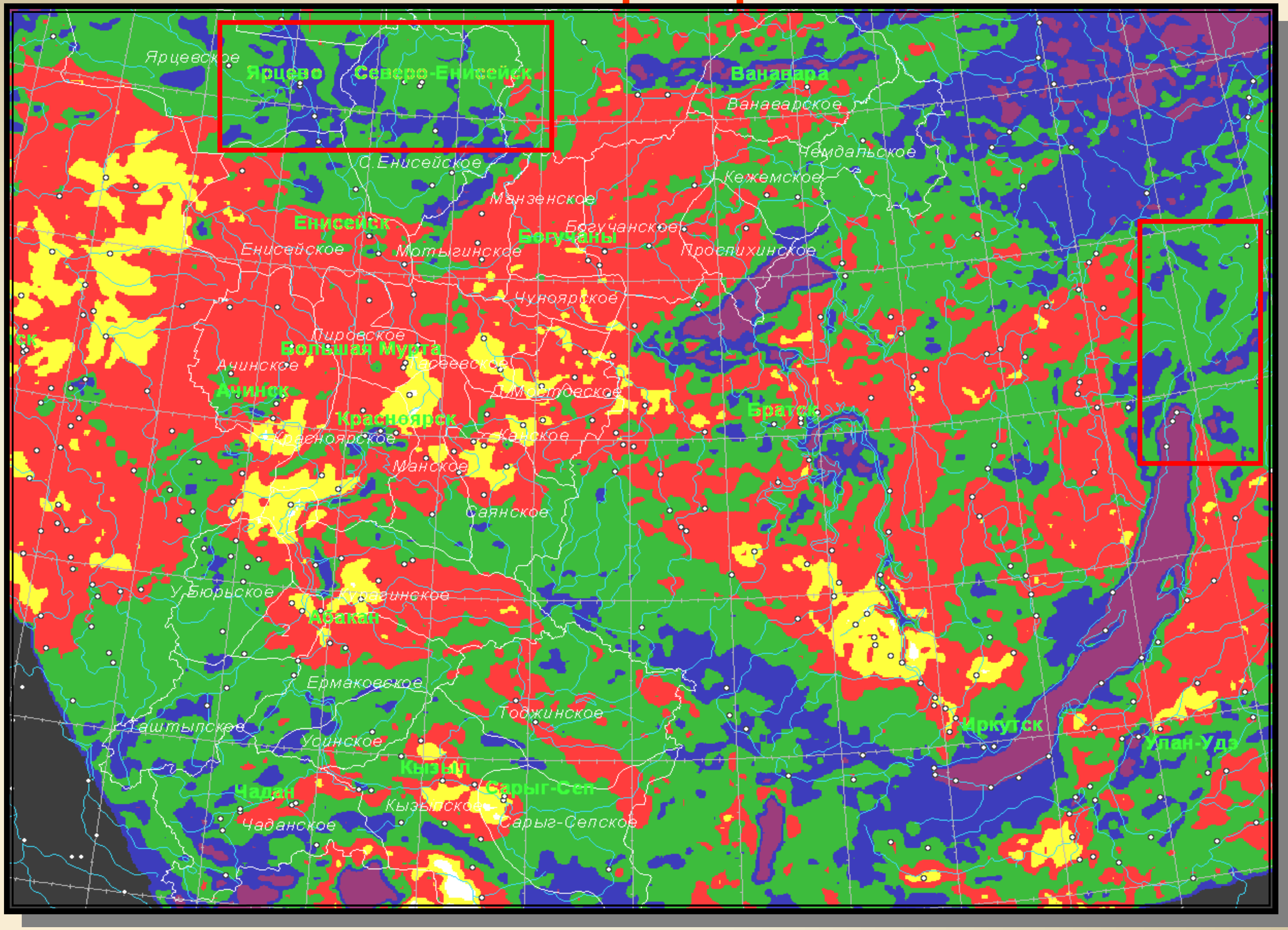




Red boxes indicate zones of liquid precipitation during the forecasting period

“B”: high; “H”: low

Schematic map of Fire danger distribution corrected for the actual precipitation



Fire Dander classes:

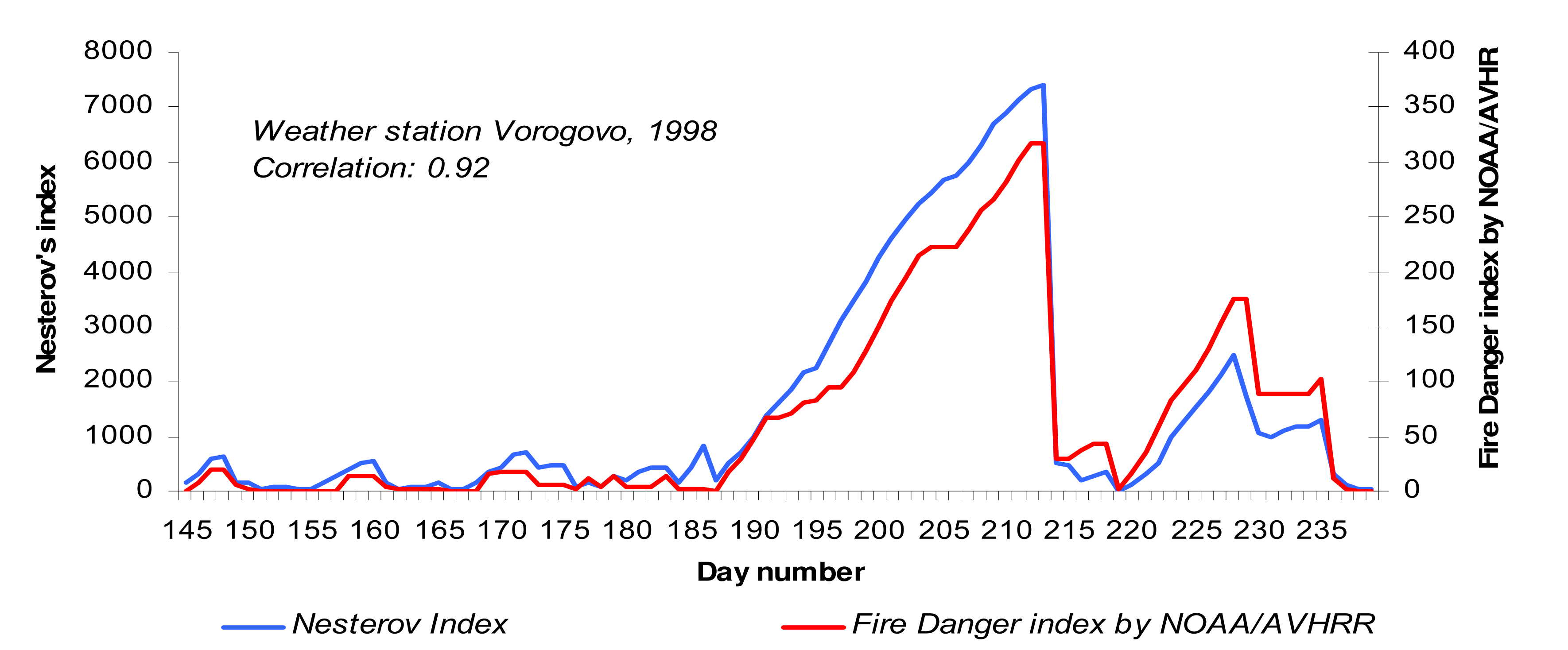
- *1 - zero*
- *2 - low*
- *3 - moderate*
- *4 - high*
- *5 - critical*
- *6 - extreme*
- *No data*

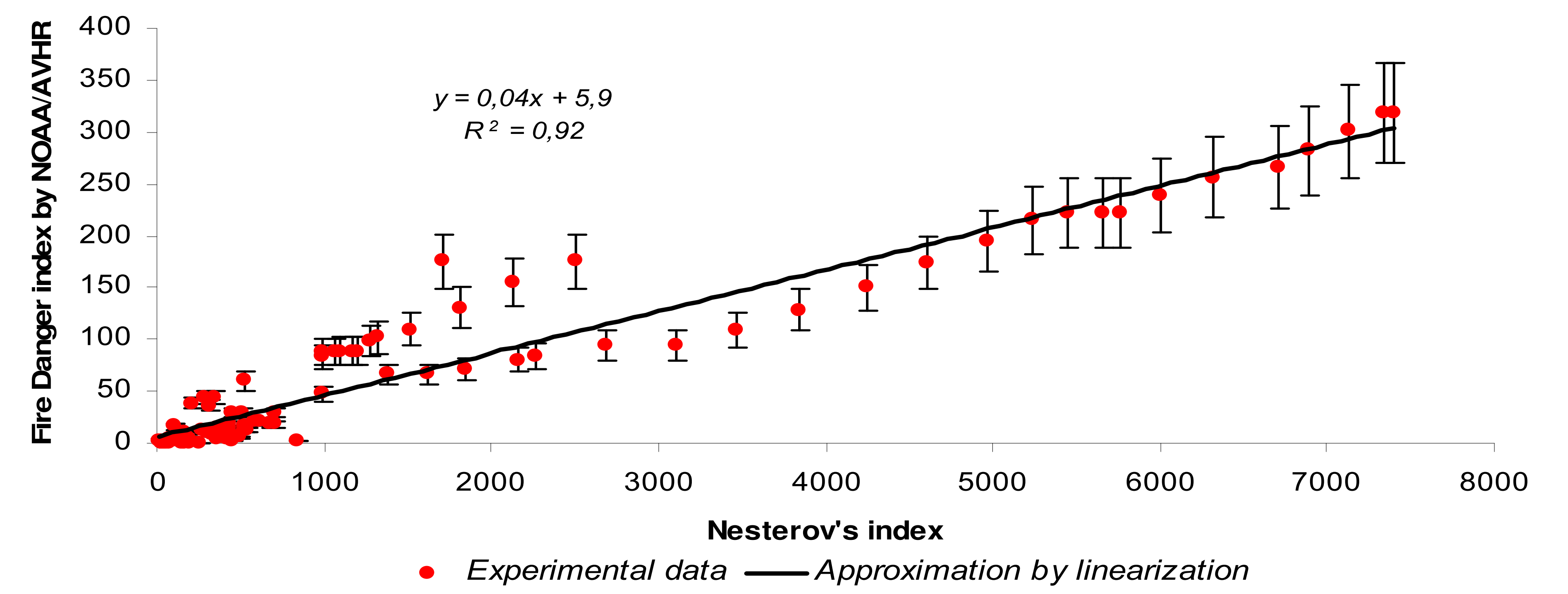
In the regions with registered precipitation fire danger classes were lowered to the 3 and 2 class in accordance with the amount of recorded precipitation. The correction is applied daily throughout the forecasting period.

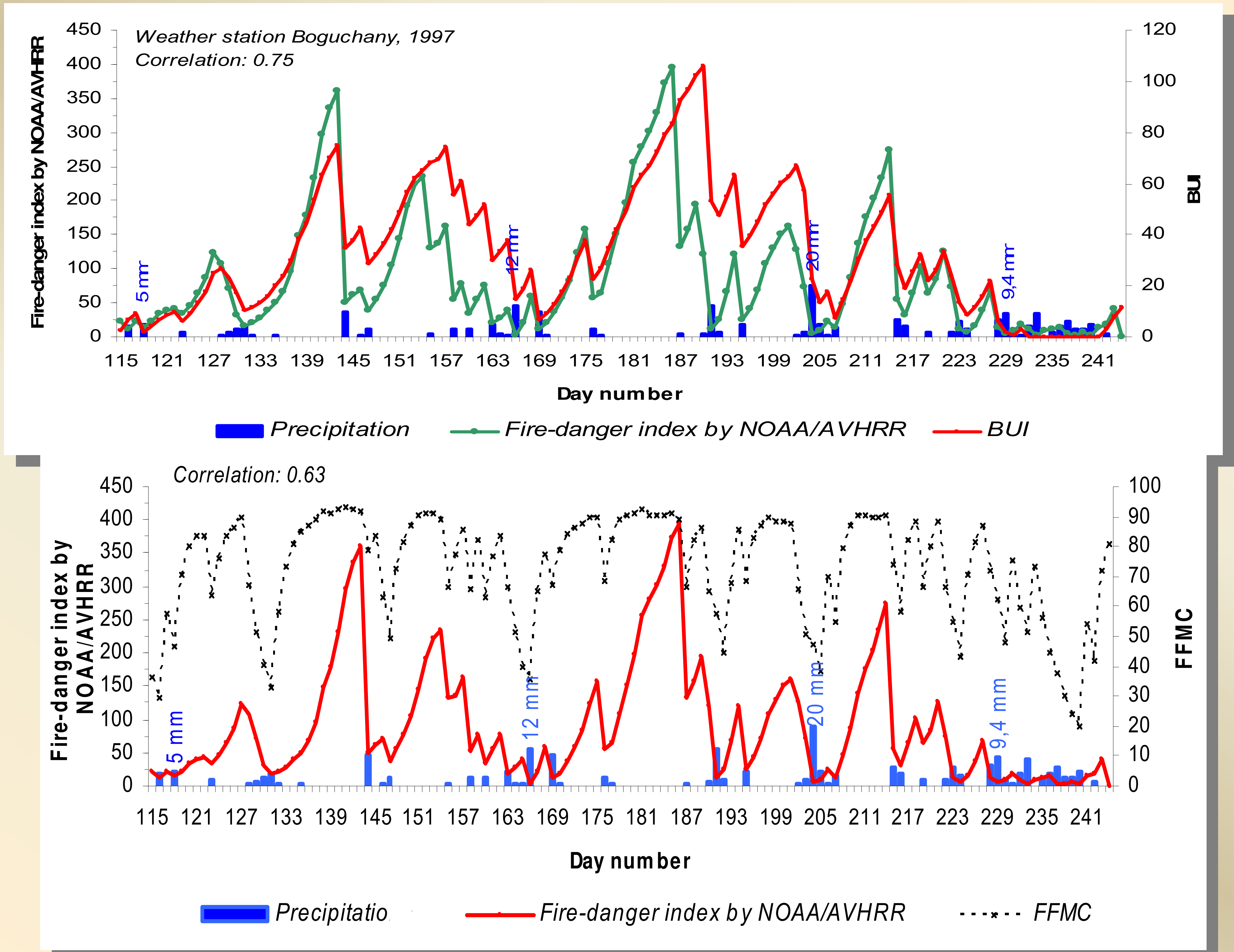
Validation

- Data from 15 on-ground weather stations in the Krasnoyarsk Region during 1996-2000
- High correlation between our fire-danger index created using remote-sensing data with the Russian Nesterov's index ($r \approx 0.9$)

Weather stations	Correlation
Strelka	0.86
Motygino	0.74
Boguchany	0.97
Aban	0.88
Vorogovo	0.92
Alexandrovski shluz	0.97
Severo-Yeniseysk	0.96
Poligus	0.98
Baykit	0.95
Vanavara	0.93
B. Uluy	0.88
Kacha	0.89
Artemovsk	0.86
Nizhneusinskoye	0.89


Weather station Vorogovo, 1998
Correlation: 0.92
Nesterov's index
Fire Danger index by NOAA/AVHRR
Day number
8000
7000
6000
5000
4000
3000
2000
1000
0
400
350
300
250
200
150
100
50
0
145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235
Nesterov Index
Fire Danger index by NOAA/AVHRR


y = 0,04x + 5,9
R² = 0,92
Fire Danger index by NOAA/AVHR
Nesterov's index
400
350
300
250
200
150
100
50
0
0 1000 2000 3000 4000 5000 6000 7000 8000
Experimental data
Approximation by linearization



Weather station Boguchany, 1997
Correlation: 0.75
Fire-danger index by NOAA/AVHRR
BUI
5 mm
12 mm
20 mm
9,4 mm
Day number
Precipitation
Fire-danger index by NOAA/AVHRR
BUI
Correlation: 0.63
Fire-danger index by NOAA/AVHRR
FFMC
5 mm
12 mm
20 mm
9,4 mm
Day number
Precipitatio
Fire-danger index by NOAA/AVHRR
FFMC

References

Fire maps (daily updates and archive) of the Forest Fire Research Laboratory, Remote Sensing Unit, V.N. Sukachev Institute of Forest, may be obtained:

ftp://friend:get_data@195.161.57.194/DailyData/

http://www.fire.uni-freiburg.de/current/globalfire.htm

http://www.fire.uni-freiburg.de/current/archive/archive.htm#RUSSIAN FEDERATION

Contact:

Anatoly I. Sukhinin
Forest Fire Research Laboratory, Remote Sensing Unit
V.N. Sukachev Institute of Forest, SB RAS
Krasnoyarsk, 660036 RUSSIA

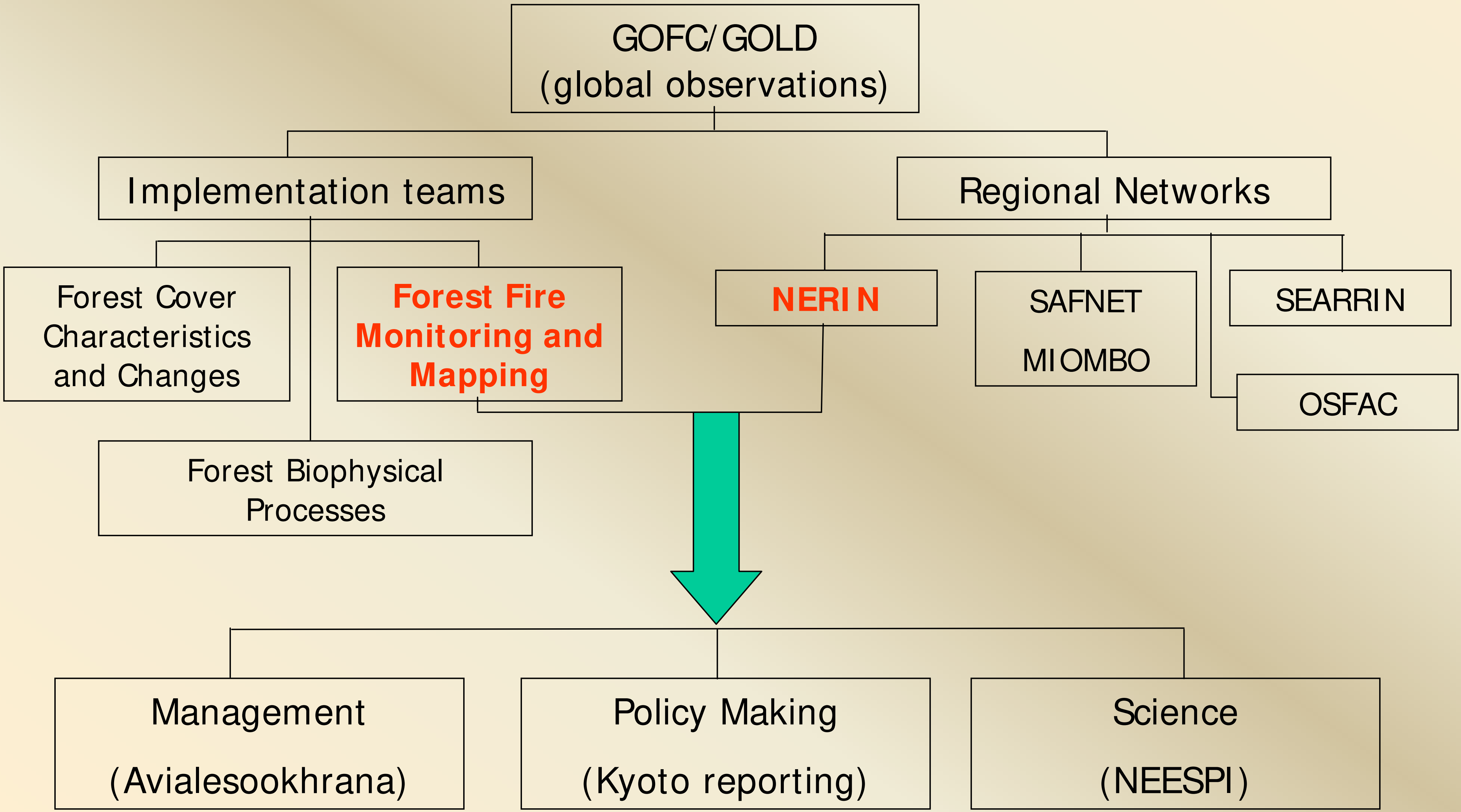
E-mail: boss@ksc.krasn.ru

Some other related NERIN-Fire activities

T. Loboda[1], I. Csiszar[1], A. Terekhov[2], D. Ershov[3], E. Loupian[4] ,O. Ravsal[5]

1 – University of Maryland, USA; 2 – Institute of Space Research, Kazakhstan; 3 – Center for Forest Ecology and Productivity, Russia; 4 – Space Research institute, Russia; 5 – JEMR, Mongolia.

NERIN-Fire

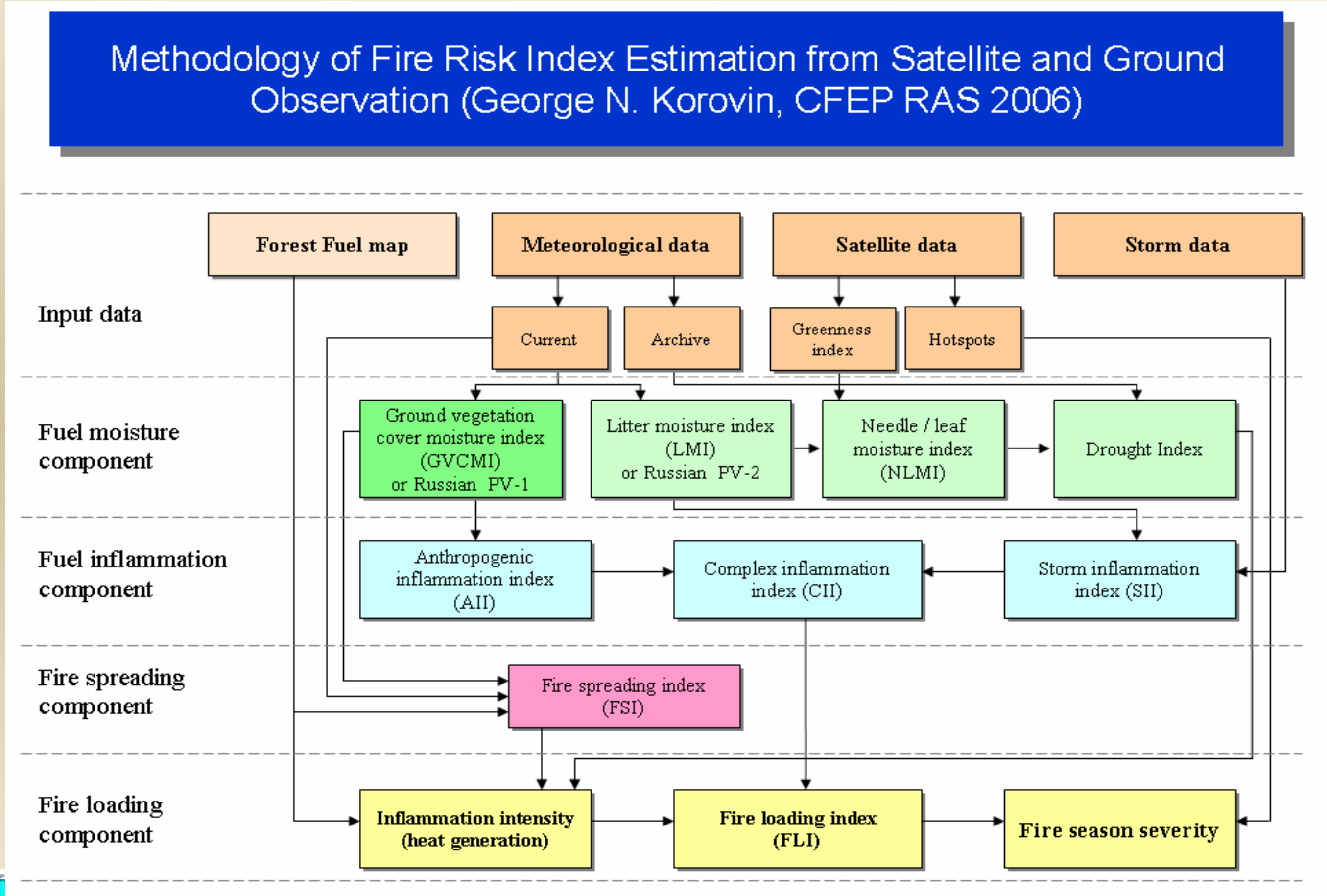


GOFC/GOLD
(global observations)
Implementation teams
Regional Networks
Forest Cover Characteristics and Changes
Forest Fire Monitoring and Mapping
NERIN
SAFNET
MIOMBO
SEARRIN
OSFAC
Forest Biophysical Processes
Management
(Avialesookhrana)
Policy Making
(Kyoto reporting)
Science
(NEESPI)

RFFDS: status and perspectives

Russian Forest Fire Danger System (RFFDS) as part of **Information System for Wildfires Remote Monitoring**

- is based on the complex meteorological index developed by V. Nesterov (FWI).
- characterizes a readiness of ignition of forest fuels as a conductor of ground forest fires.



The **RFFDS** incorporates evaluation of fuel susceptibility to fire as well as anthropogenic and natural drivers of fire ignition risk, fire spread rate, amount of released energy, fire danger, fire suppression difficulty, etc. for different forest conditions of Russia.

Predictive Early warning systems in Kazakhstan

Low precipitation amount

Fire occurrence is unlikely because of low fuel availability

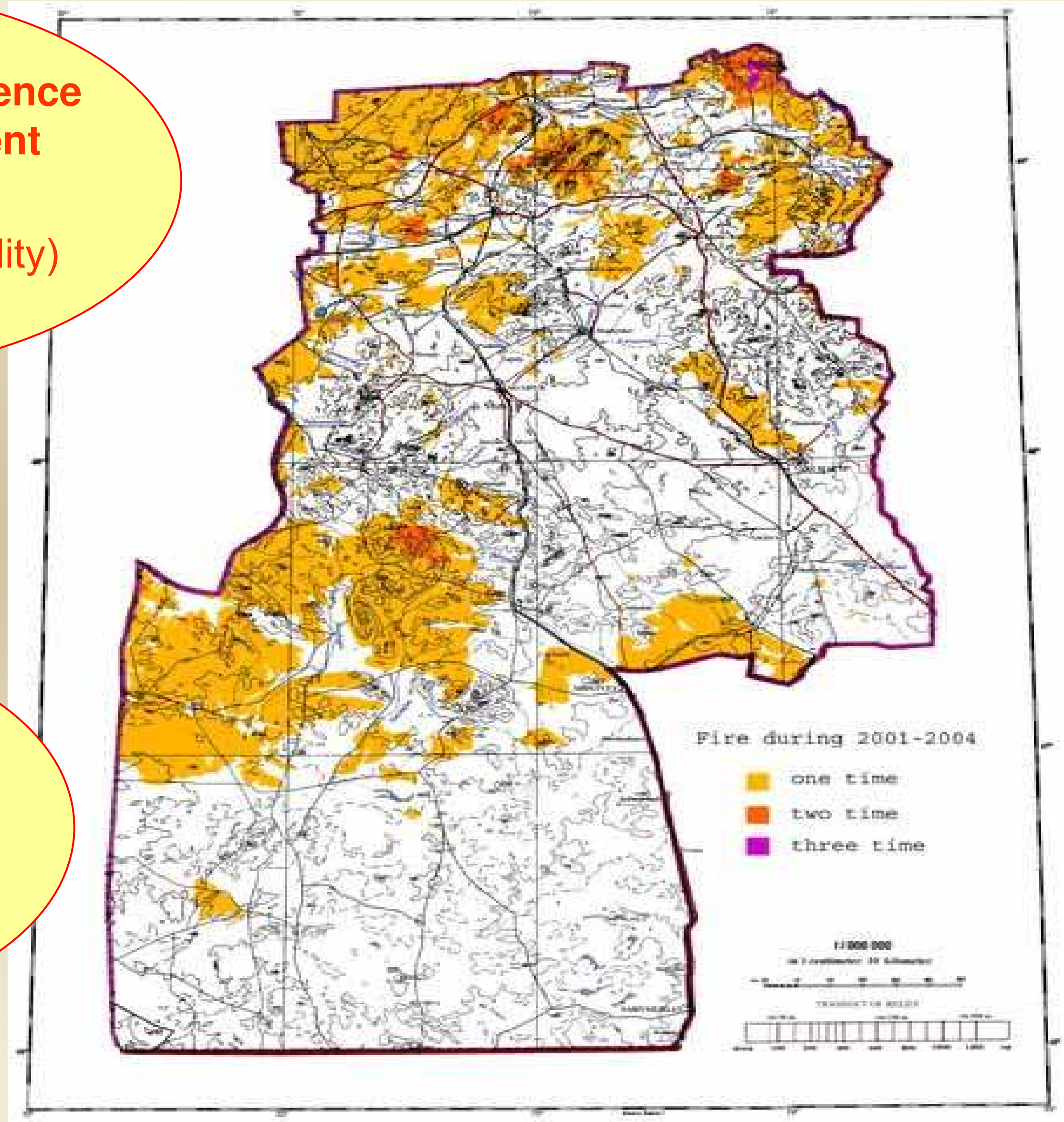
The risk of fire occurrence is not driven by current weather condition
(temperature and humidity)

High precipitation amount

Fuel build up sustains large fires: a single burn can reach the size of nearly 1 million hectares

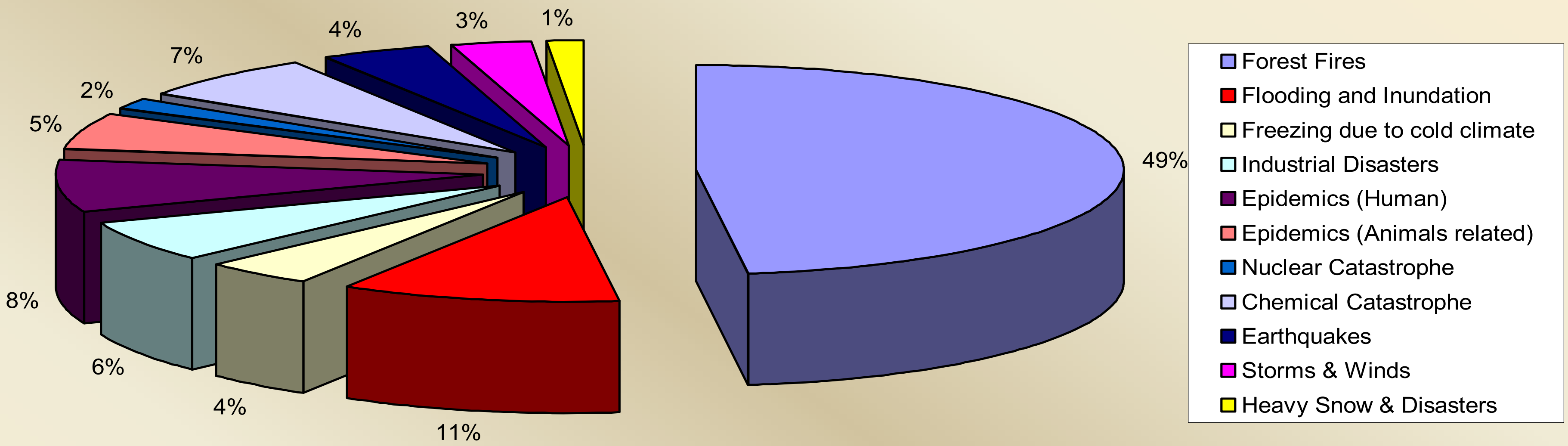
Fire risk is driven by biomass productivity of steppe ecosystem

Statistical estimation of fire risk



Frequency of steppe fire in Shetsky rayon, Karaganda oblast, KAZAKHSTAN during 2001-2004 years

Predictive Early warning systems in Mongolia



Frequency of disaster occurrence in Ulaanbaatar during 1990-2000

Integration of **information** and **communication technology** with the **indigenous knowledge** and **wisdom** and **the best practices of the developed countries** are considered as key factors towards developing an in-depth understanding, assessment and successful management to reduce disaster risks and vulnerability in Mongolia.

Fuzzy-logic driven Fire Danger Model: example from the Russian Far East