The Russian FIRE BEAR (Fire in the Boreal Eurasia Region) Project: an experimental fire study to enhance forest sustainability in central Siberia

Douglas J. McRae, Susan G. Conard,
Galina A. Ivanova, and Anatoly I. Sukhinin

Natural Resources Canada
Canadian Forest Service

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The Russian FIRE BEAR (Fire in the Boreal Eurasia Region) Project: an experimental fire study to enhance forest sustainability in central Siberia

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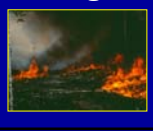
Experimental fire: Set to meet research objectives for mimicking actual fire conditions (e.g., fire behavior prediction, fire impacts, etc.)

Prescribed fire: Set to meet operational objectives (e.g., forest site preparation, agricultural stubble burning, etc.)



Research Collaborators:

Federal Forest Service of Russia

- Forestry Committee of Krasnoyarsk Region
- Forest Protection Airbase, Krasnoyarsk Region

Russian Academy of Science, Siberian Branch

- V.N. Sukachev Institute of Forest, Krasnoyarsk
- Institute of Chemical Kinetics and Combustion, Novosibirsk

Universities

- Moscow State University
- Siberian Technological University
- University of Virginia

USDA Forest Service

- Washington DC
- Rocky Mountain Forestry Station
- International Projects

Canadian Forest Service

- Great Lakes Forestry Centre

Background

- Globally there are about 1.2 billion ha of boreal forest and woodlands

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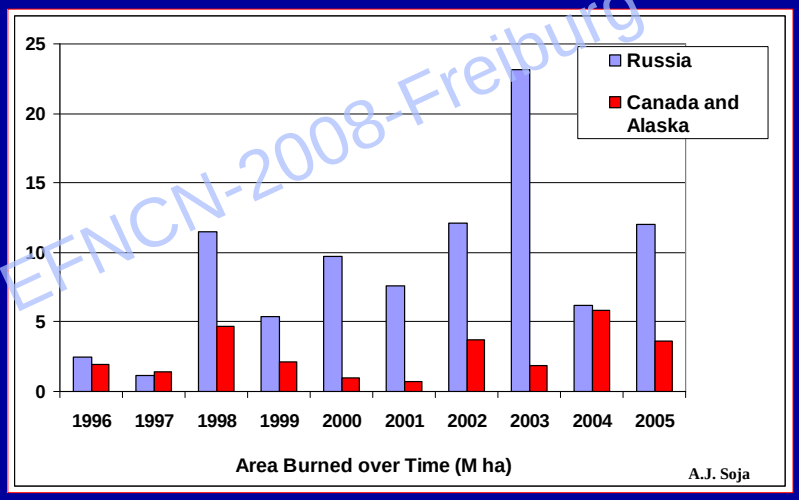
- Over 30 % of the global terrestrial biomass is in boreal forests (2/3 of this in Russia).
- Wildland fire affects 10 to 15 million ha of boreal forest annually.

Annual Burn Area in the Boreal Region



Background

- Globally there are about 1.2 billion ha of boreal forest and woodlands
- Over 30 % of the global terrestrial biomass is in boreal forests (2/3 of this in Russia).
- Wildland fire affects 10 to 15 million ha of boreal forest annually.
- Interest in fire emissions and impact on climate change.

Smoke from Siberia over Quebec in May 2003

Fire in the Russian Boreal Forest

- Fires in the Russian boreal are dominated by surface fire, but quantitative fire models are not available.


Canada: Crown fires


Russia: Surface fires

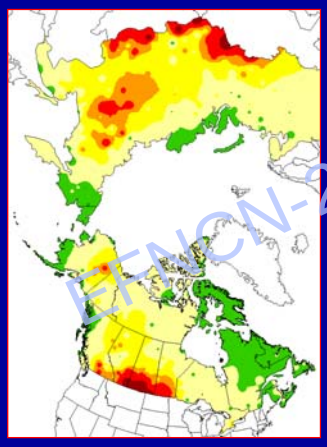
80%

Fire in the Russian Boreal Forest

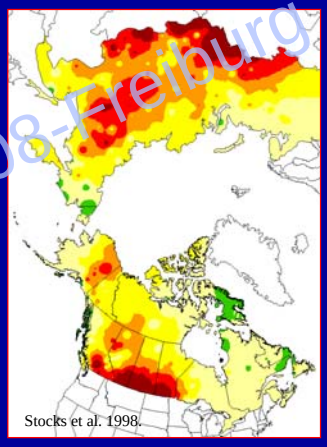
- Fires in the Russian boreal are dominated by surface fire, but quantitative fire models are not available.
- Lack of data linking fire severity to effects on emissions or ecosystem response and recovery.

Potential Effect of Climate Change on fire hazard in the Boreal Zone

June



Historical Fire Weather



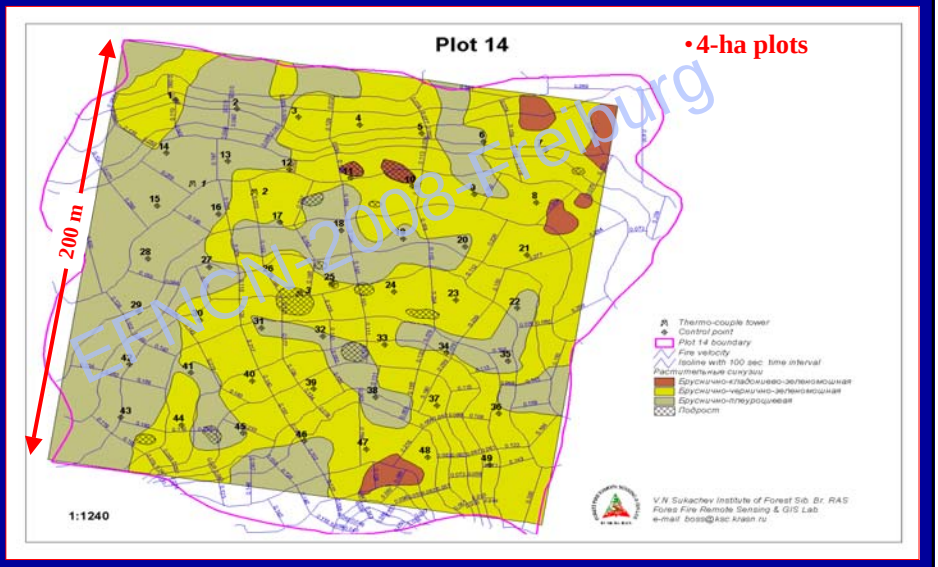
Stocks et al. 1998.

Future Fire Weather (GCM: 2X CO_2)

Experimental fire locations

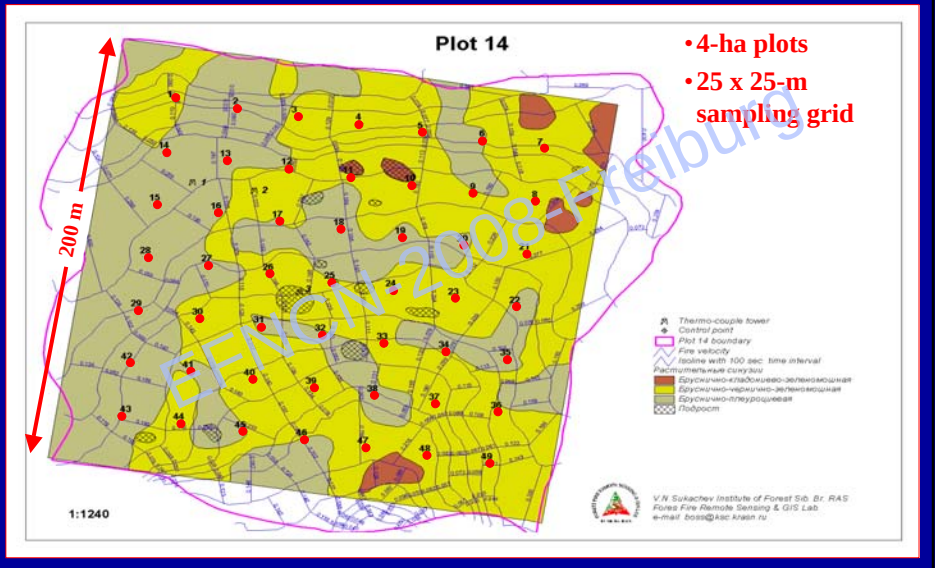
Yartsevo site: Scots pine on dry sites

Ground sampling



- 4-ha plots

Ground sampling



- 4-ha plots
- 25 x 25-m sampling grid

Fire weather and Canadian Forest Fire Weather Index System component values at time of burning

Fire	Temp (°C)	RH (%)	Wind (km/h)	Rain (mm)	Canadian Forest Fire Weather Index System					
					FFMC	DMC	DC	BUI	ISI	FWI
Yartsevo site										
2	27	32	10.2	2.0	84.9	16.9	104	24.0	3.4	6.3
3a	14.1	95	3.6	0.7	73.7	27.4	193	40.4	0.9	1.8
3b	18.2	43	9.7	1.0	76.0	18.9	189	30.2	1.3	2.6
4	27.6	50	1.8	0.0	87.7	28.5	285	45.6	3.2	8.7
6	22.4	52	2.6	0.0	88.1	28.2	217	42.6	3.7	9.5
13	24.2	45	3.6	0.0	89.2	36.1	401	58.9	4.0	12.2
14	26.4	21	1.0	0.0	92.8	50.5	393	76.4	8.5	24.7
19	21.2	40	0.8	0.0	86.9	23.4	202	36.4	2.8	6.8
20	20.6	41	9.3	0.0	88.7	29.2	261	45.7	5.7	13.9
21	23.2	37	1.2	0.0	87.6	31.1	269	48.2	3.1	8.7
21P	21.3	49	0.4	0.0	89.5	32.0	269	49.3	4.2	11.5
Govorkova site										
1	24.3	26	9.9	0.0	91.5	17.5	113	25.2	5.8	10.3
2	24.2	24	2.0	0.0	92.8	22.2	121	30.4	7.0	13.1

Preliminary Experimental Fire Results

Low-intensity Surface Fires

Plot 3 - July 23, 2001

Plot 3 - July 26, 2001

Low-intensity Surface Fires

Moderate-intensity Surface Fires

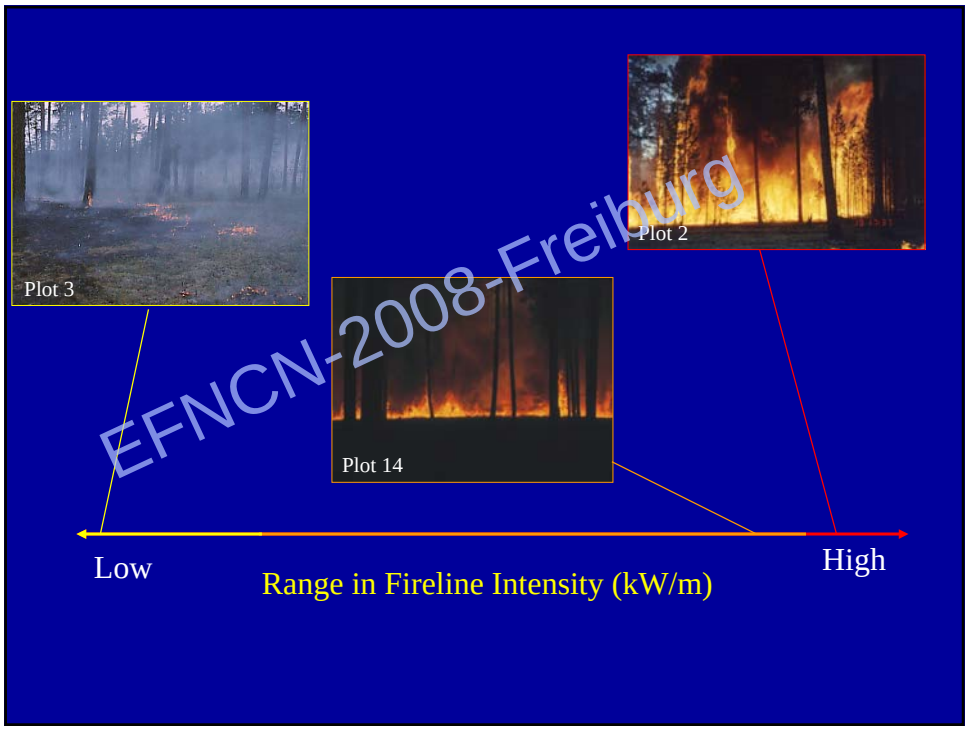
Plot 19 - July 28, 2001

Plot 6 - July 30, 2001

High-intensity Surface Fires

High-intensity Surface Fire

High-intensity Crown Fires


Plot 3
Plot 2
Plot 14
Low
High
Range in Fireline Intensity (kW/m)
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Fuel Sampling
Down woody fuels
Surface fuels
Fuel moisture
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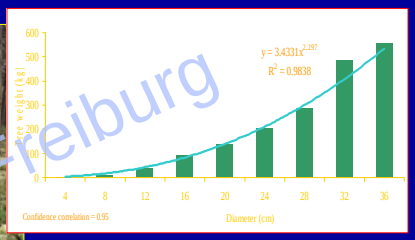
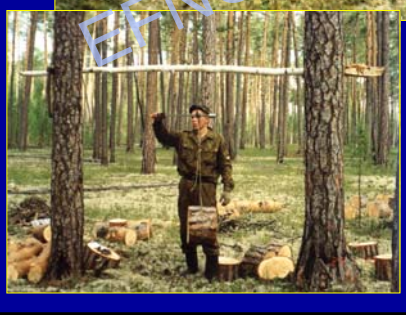
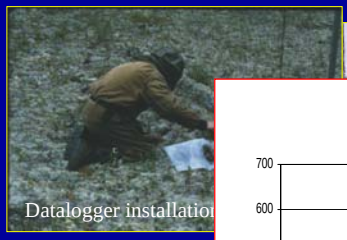
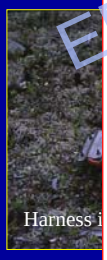
Crown Fuel Loading Sampling

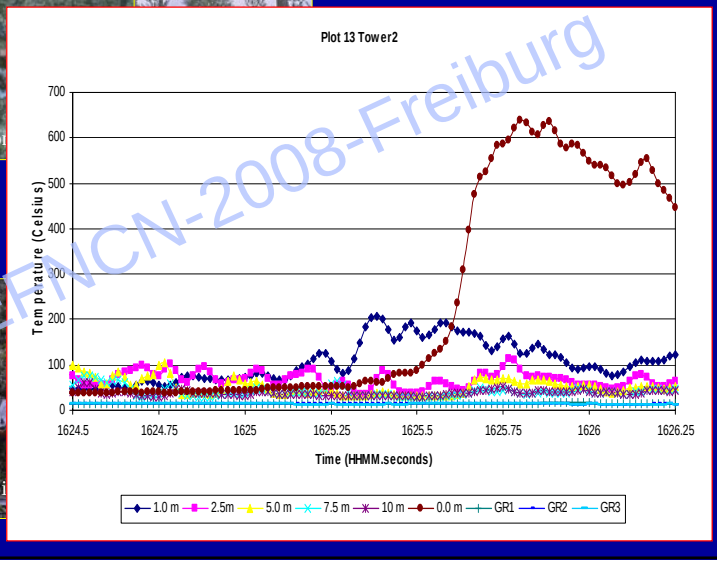




Temperatures (Above and Below Ground)

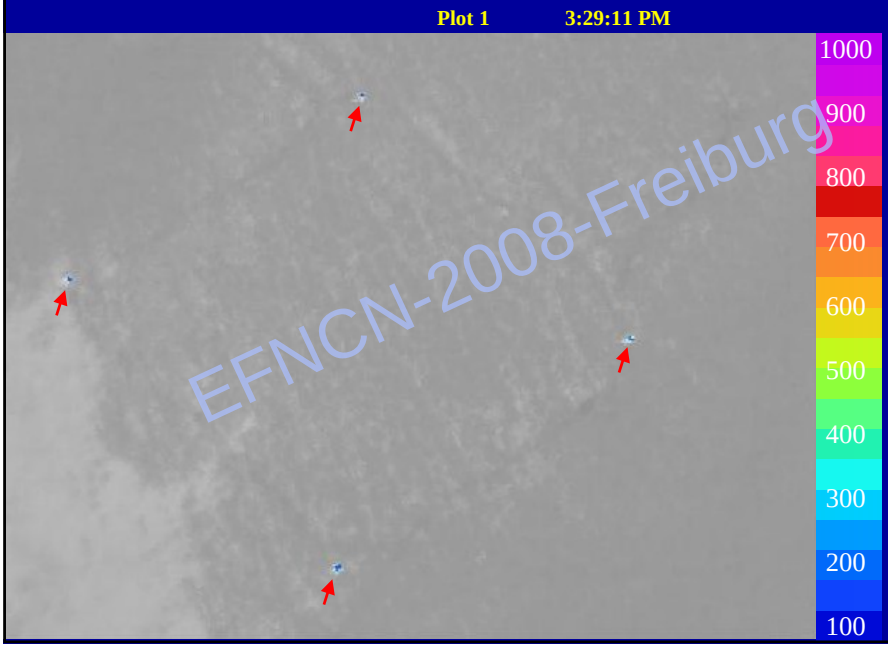


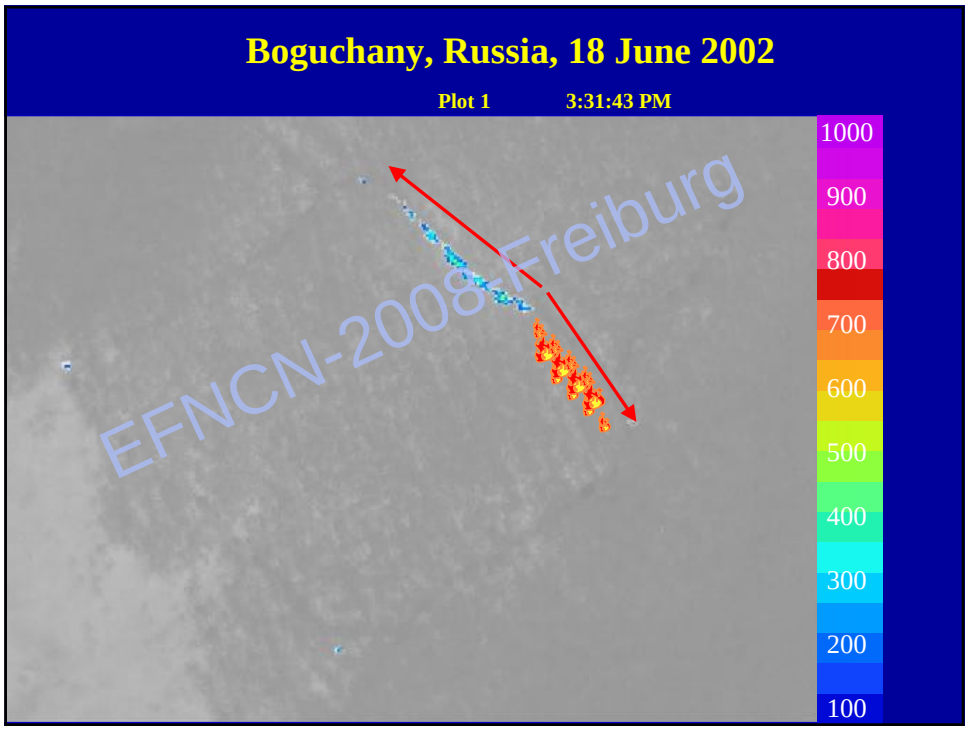




Digital Infrared Imagery

Boguchany, Russia, 18 June 2002

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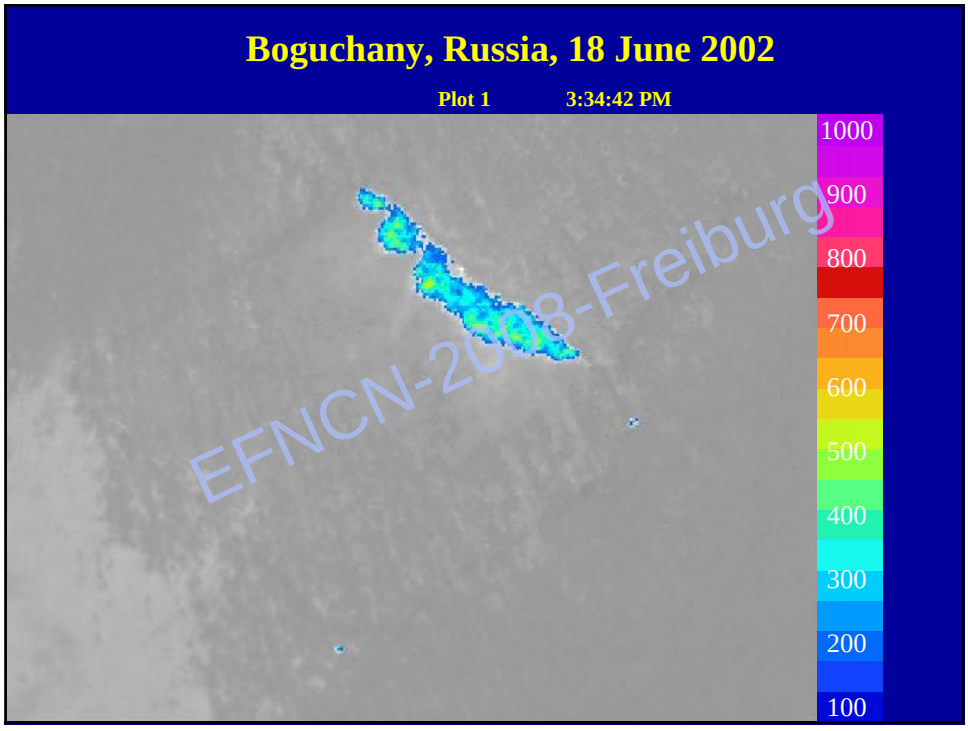
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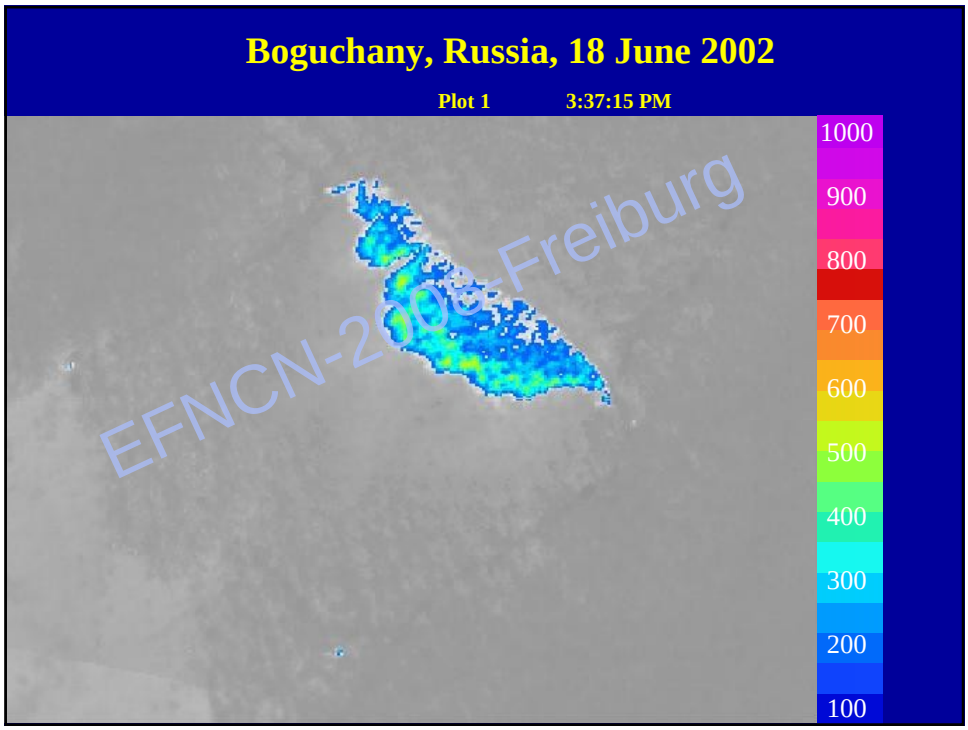
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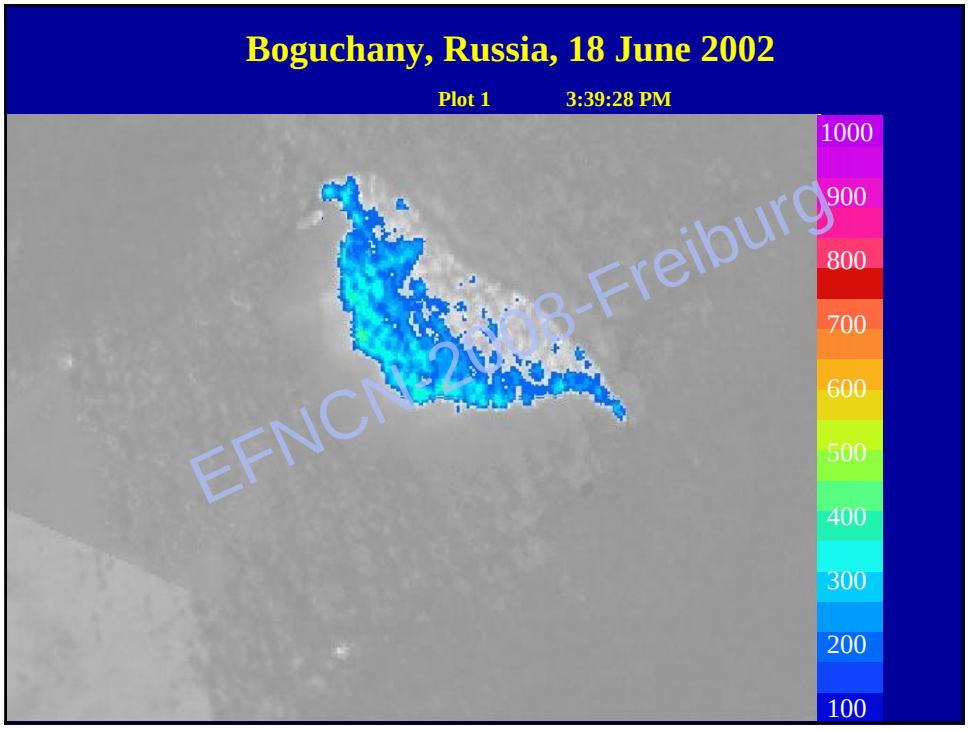
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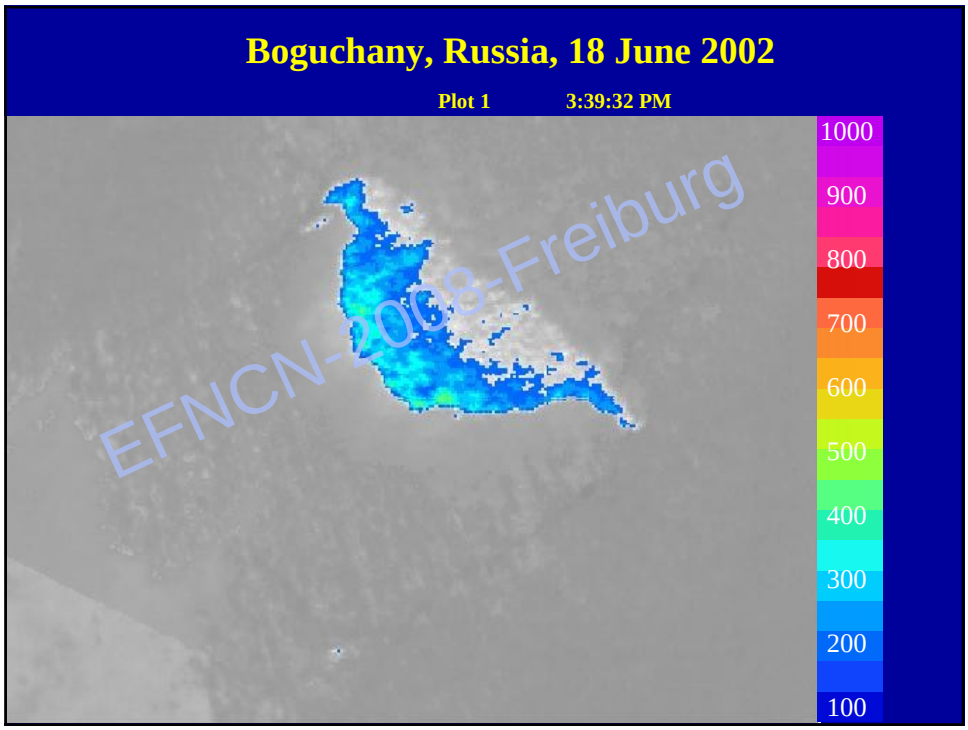
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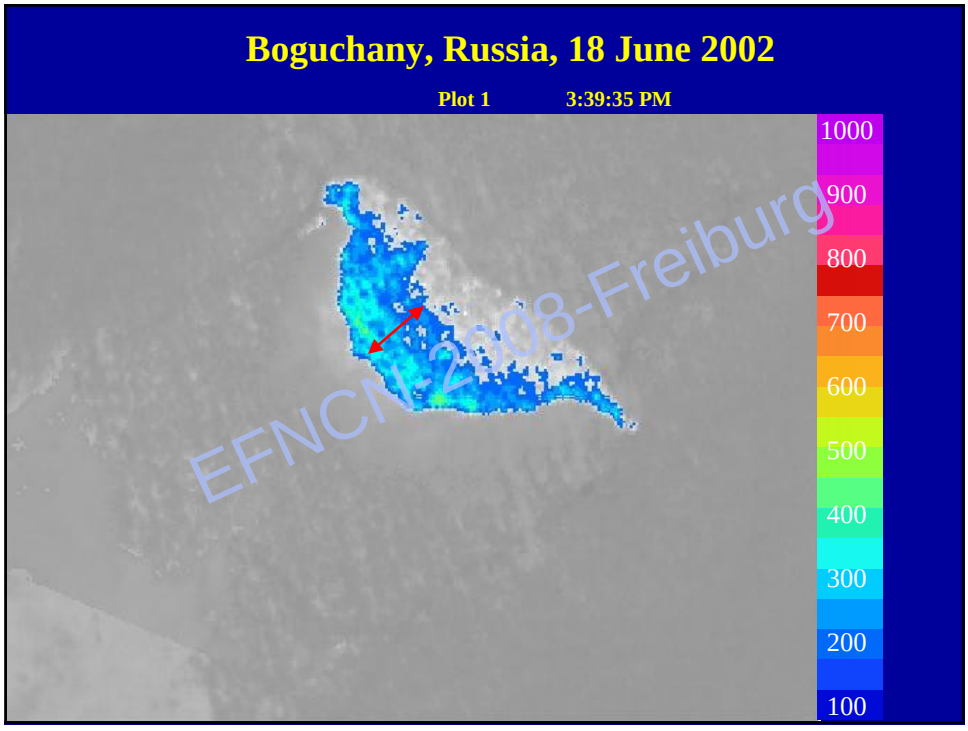
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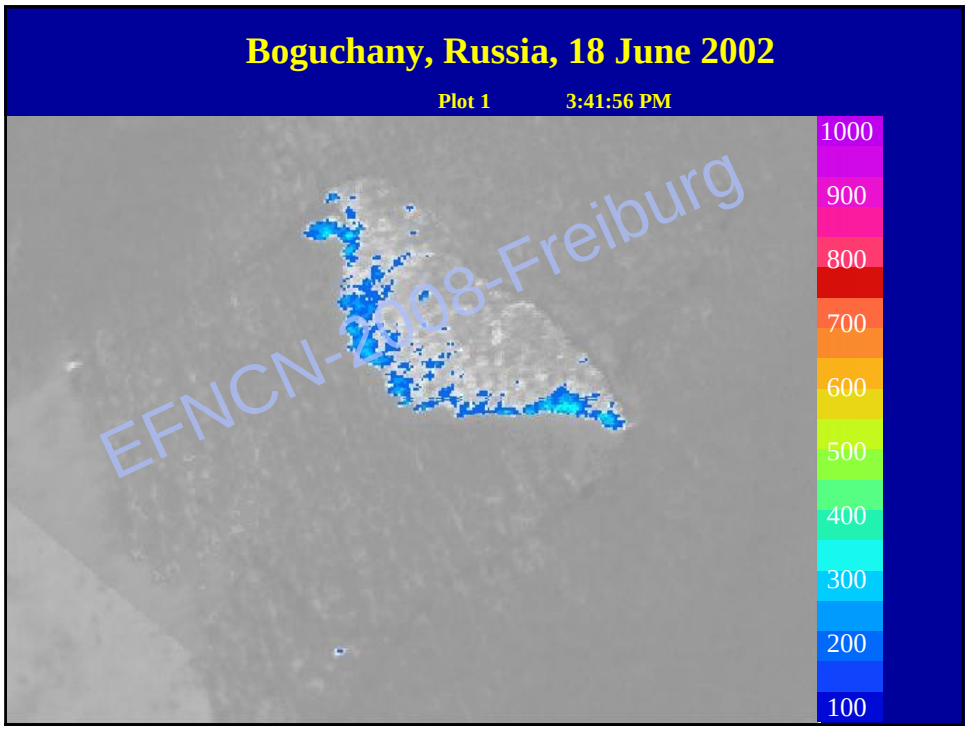
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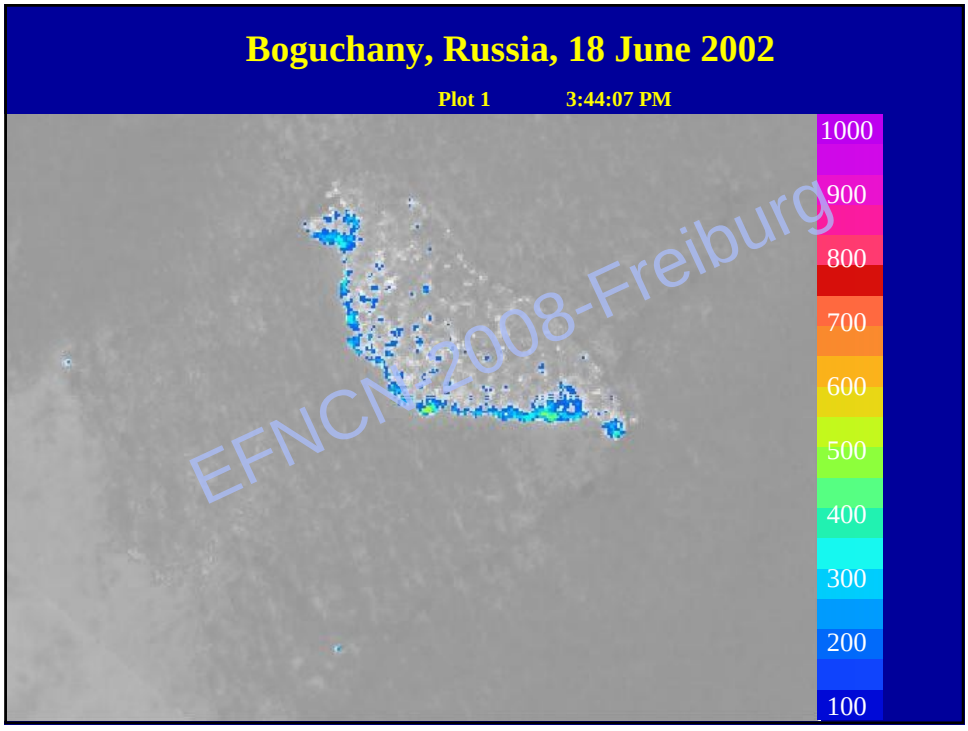
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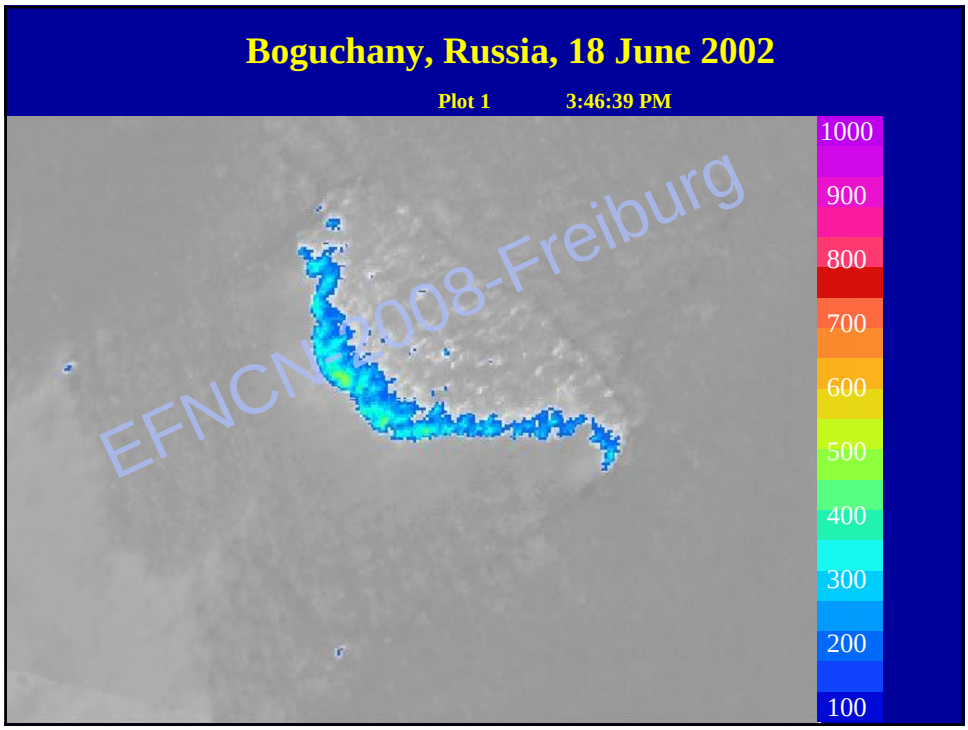
EFNCN-2008-Freiburg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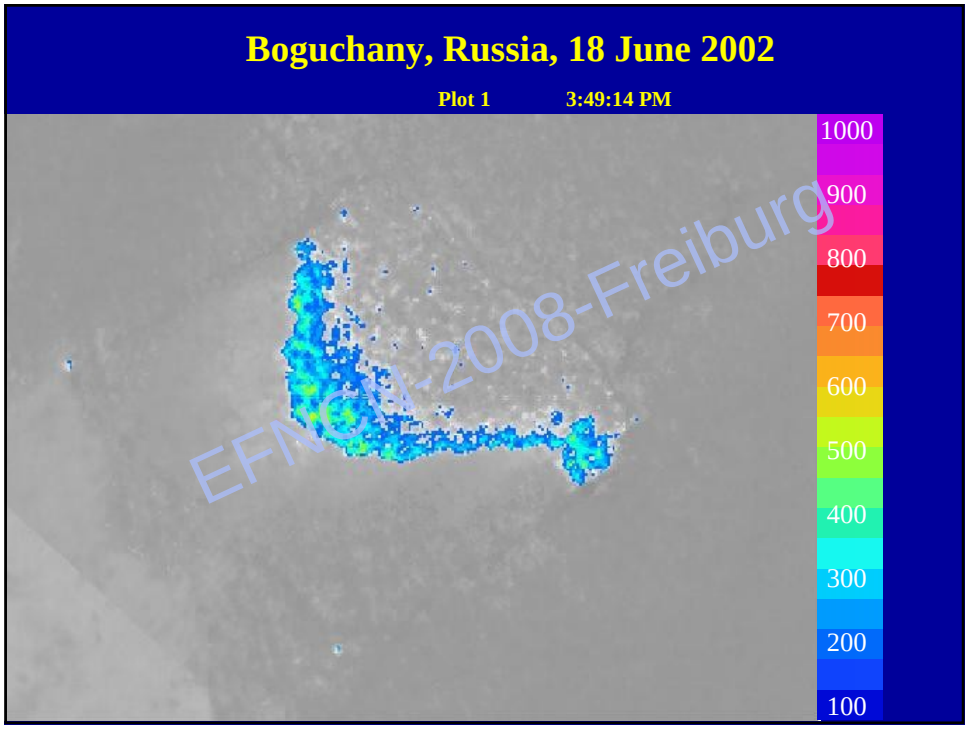
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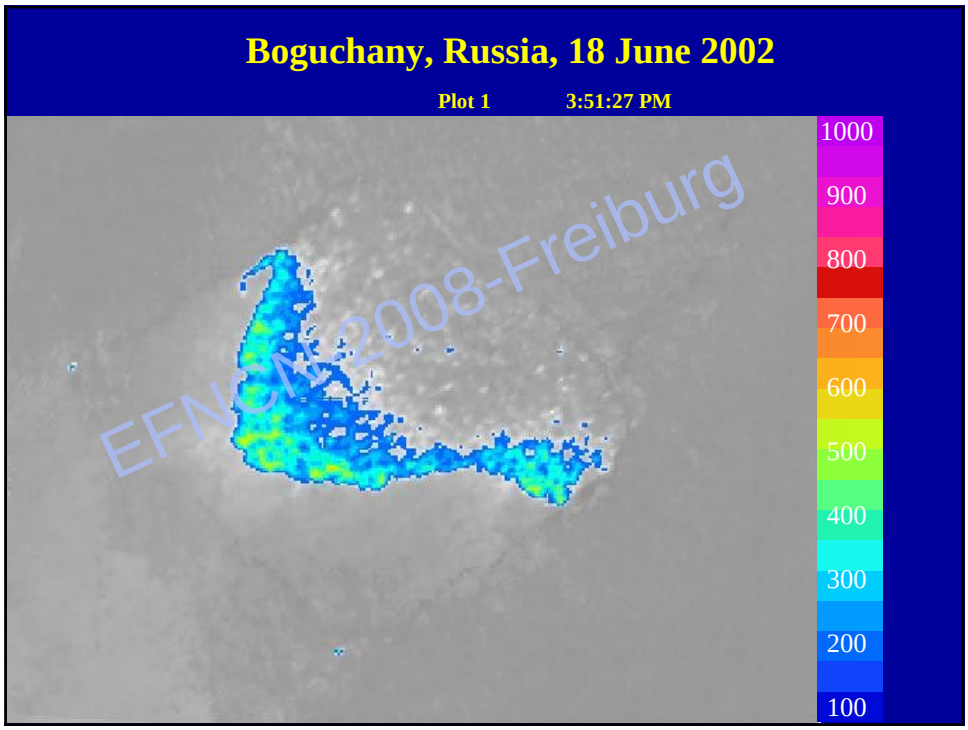
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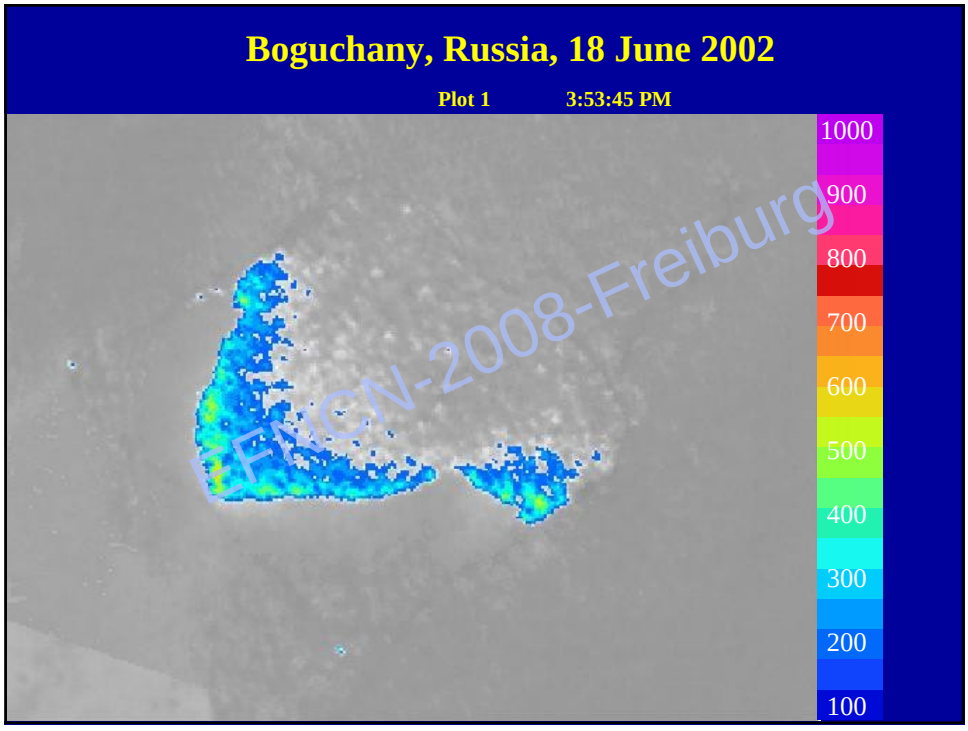
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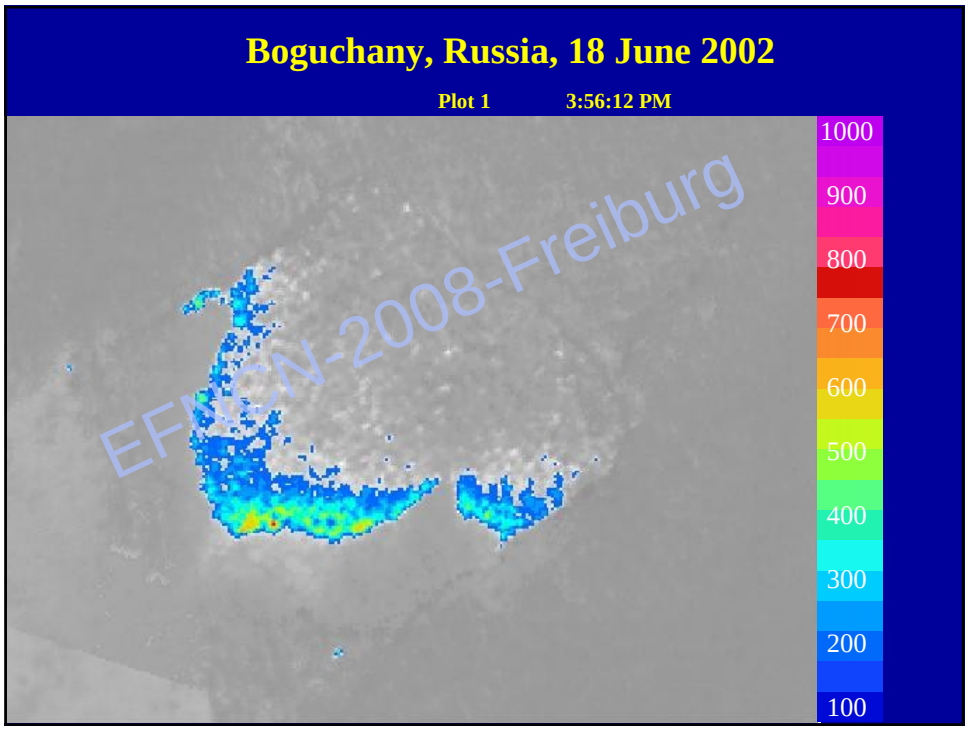
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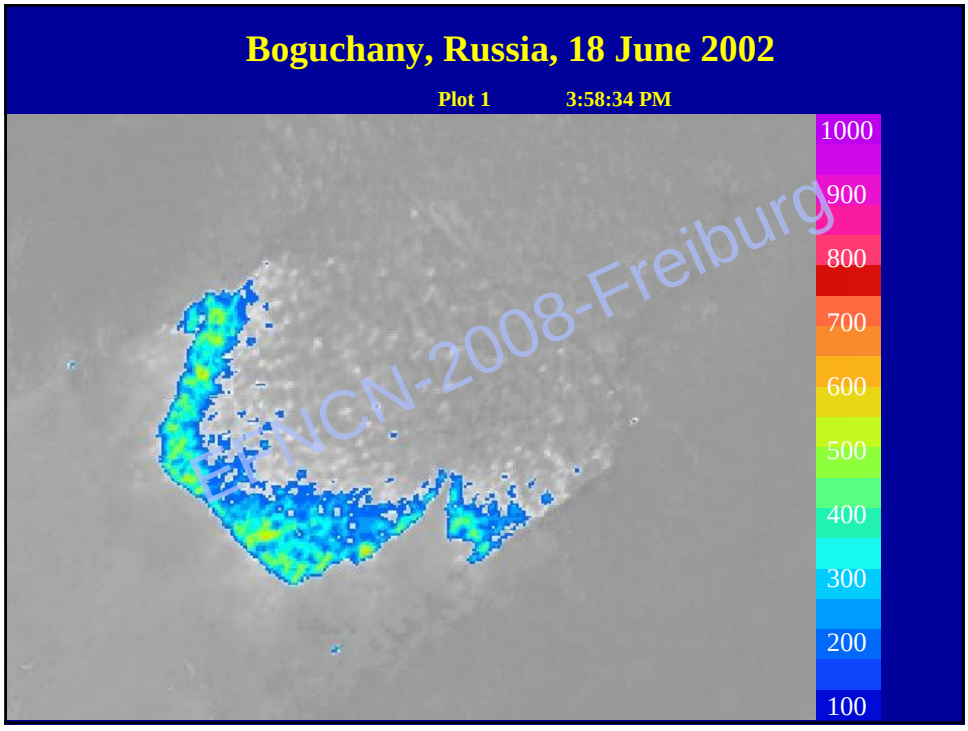
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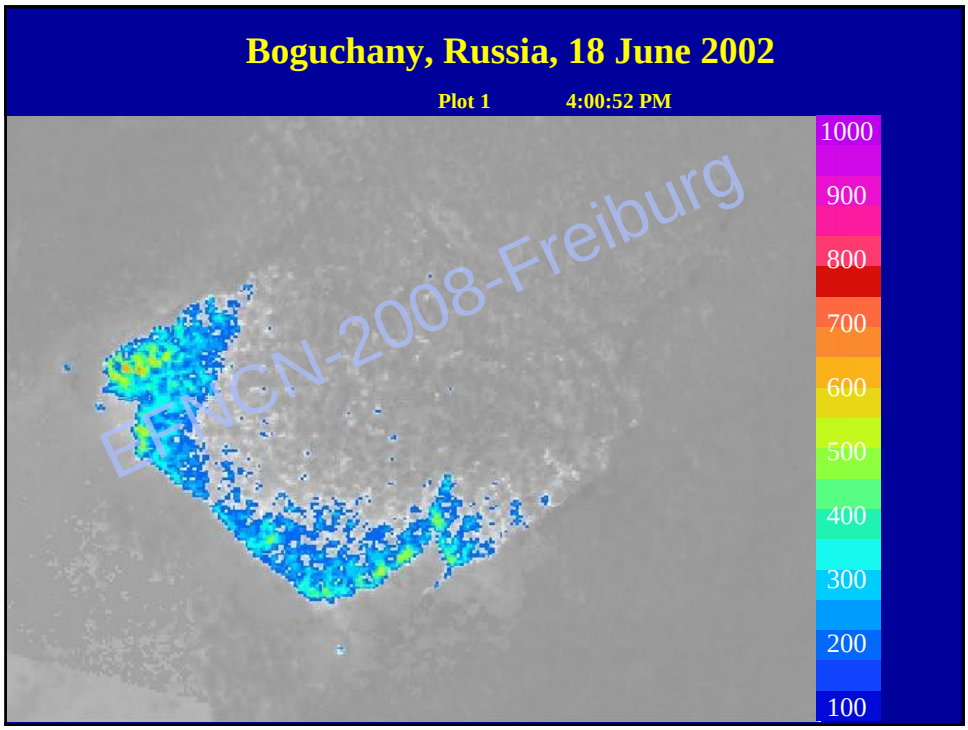
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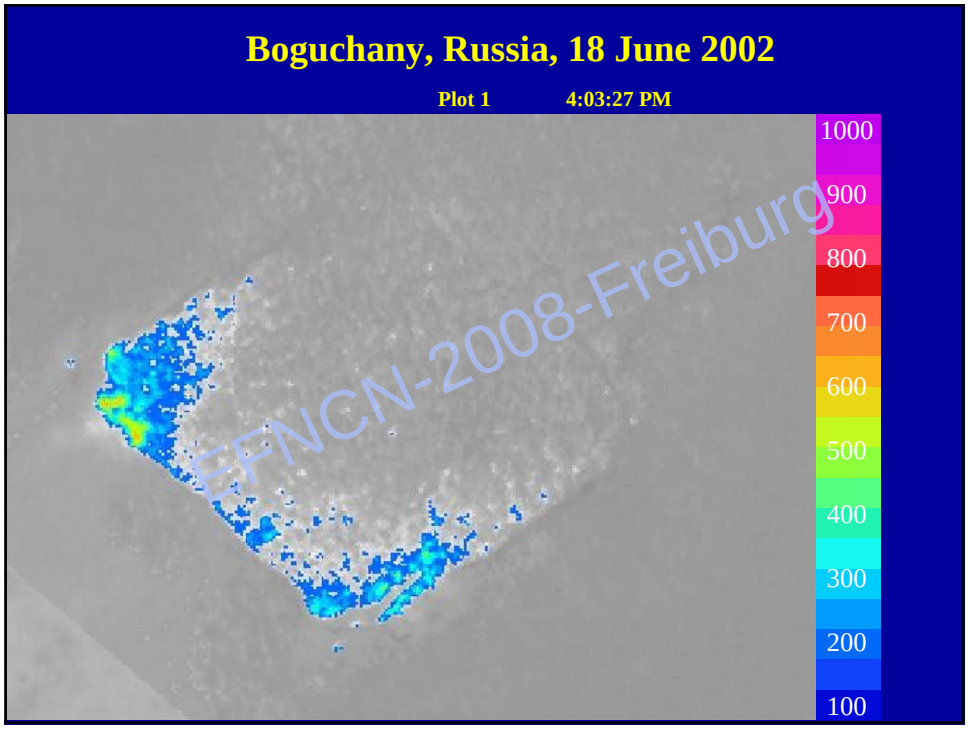
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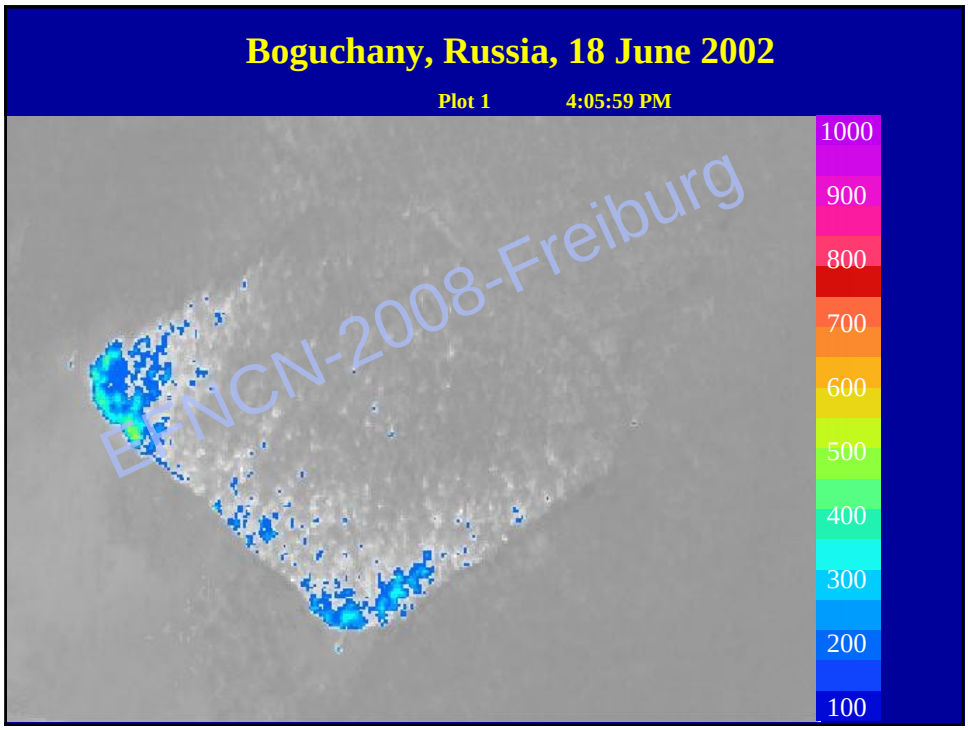
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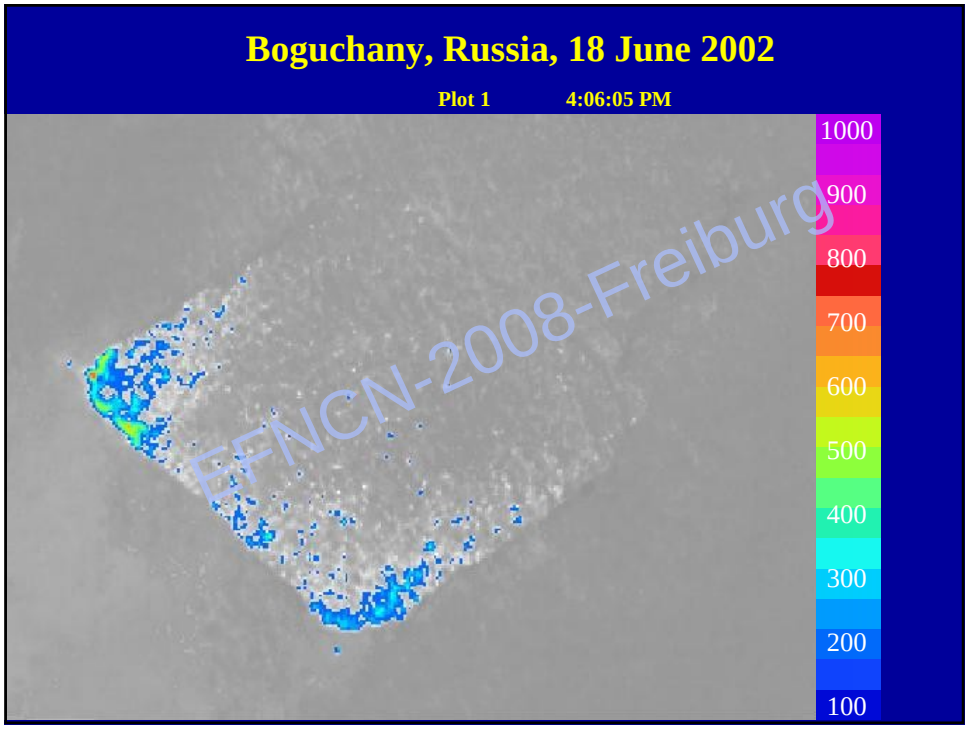
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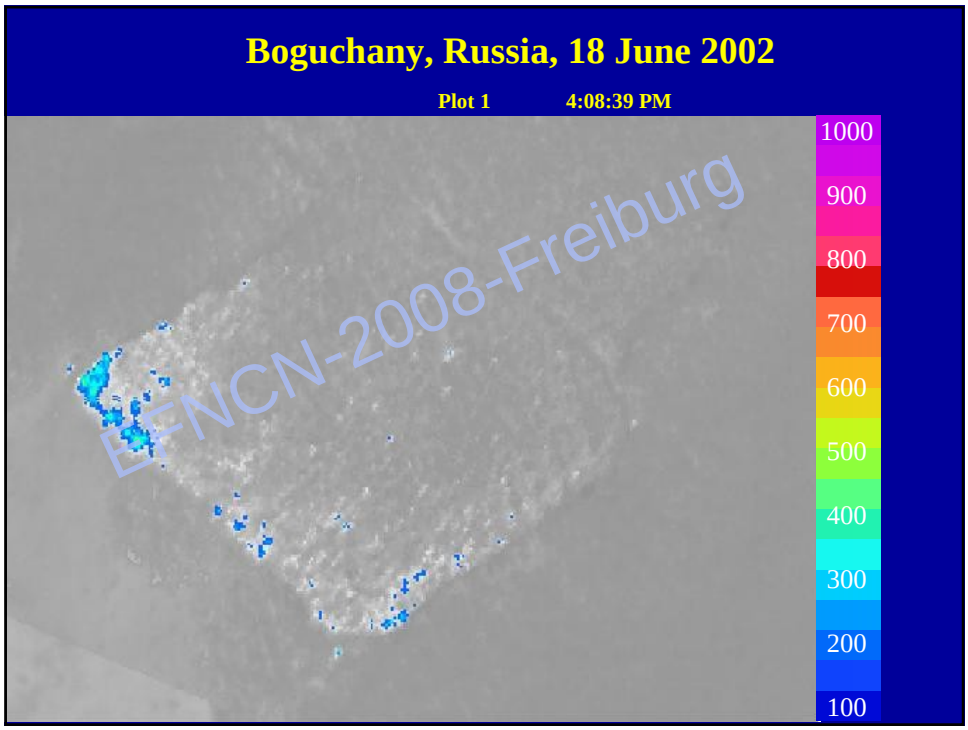
Boguchany, Russia, 18 June 2002
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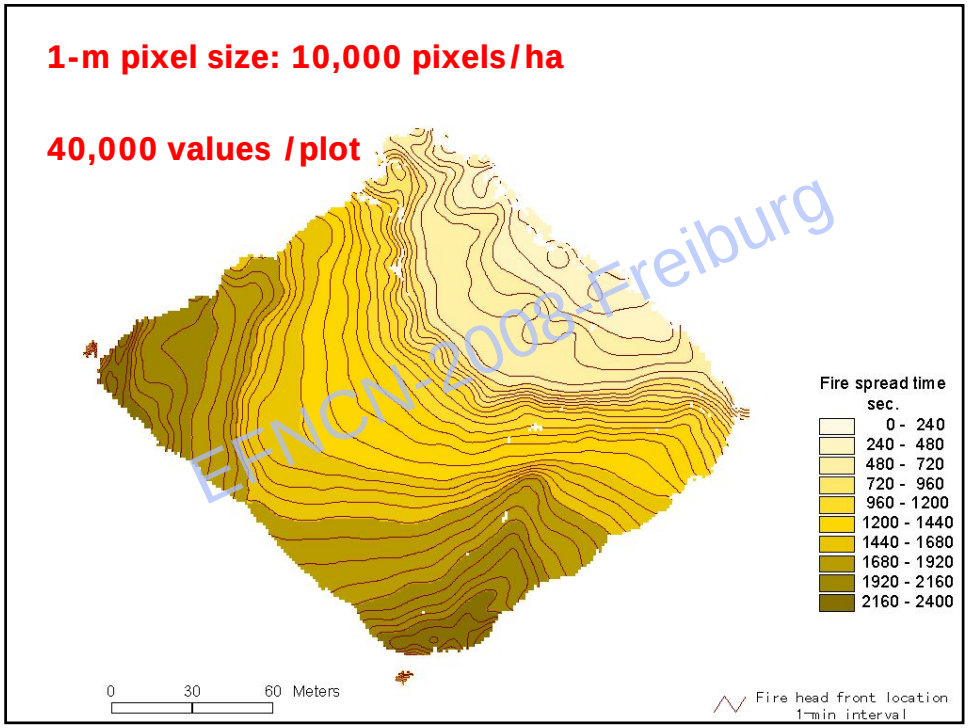
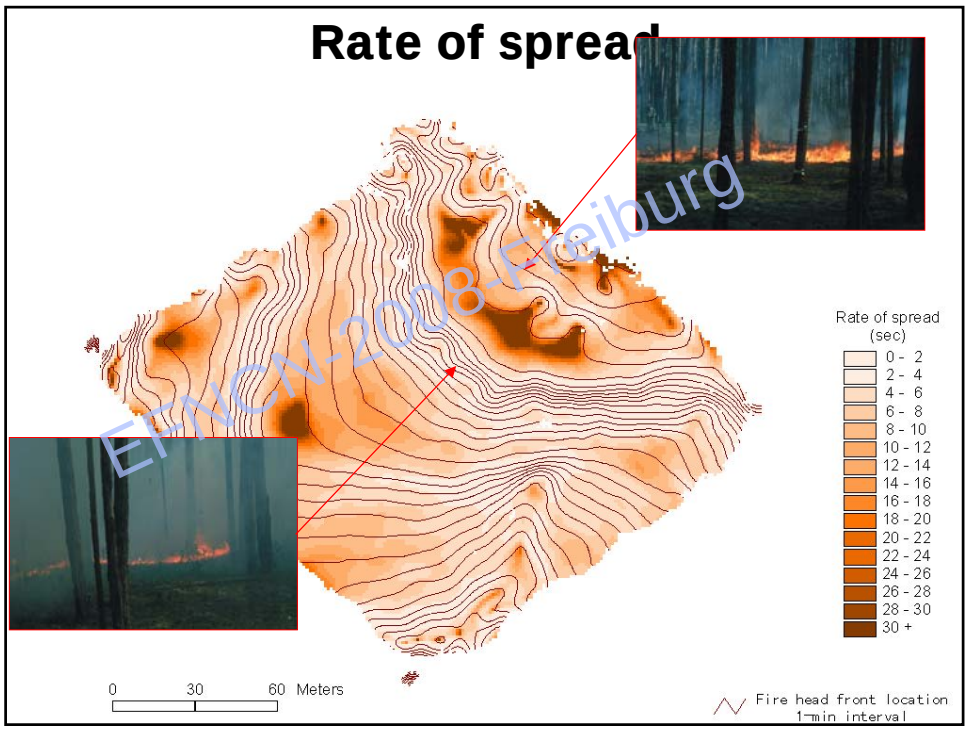
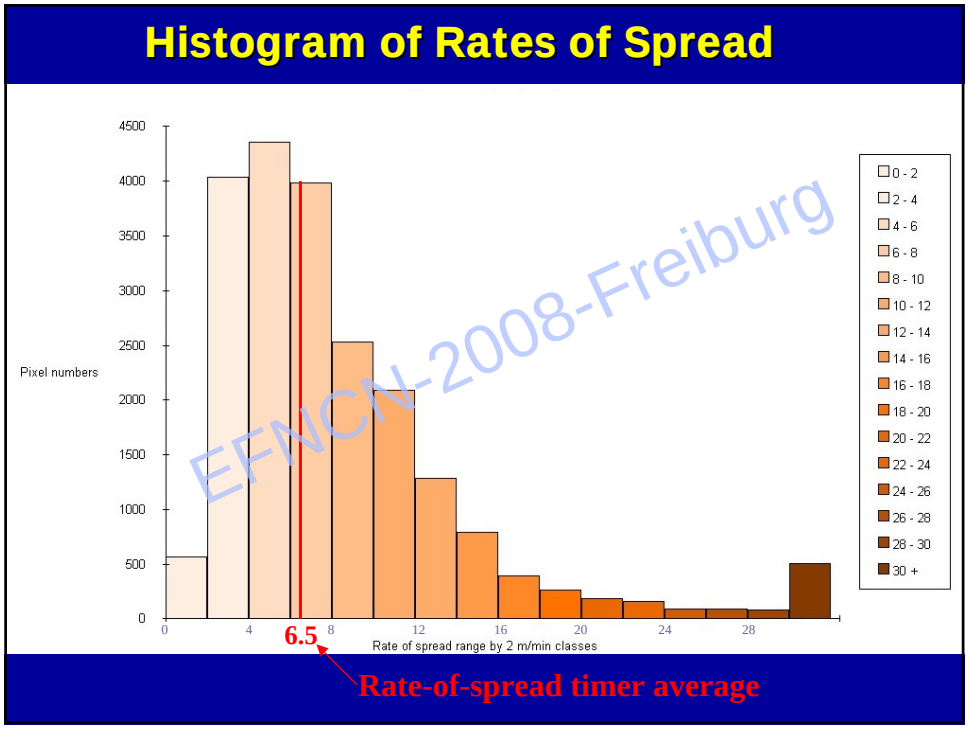

1-m pixel size: 10,000 pixels/ha
40,000 values /plot
Fire spread time
sec.
0 - 240
240 - 480
480 - 720
720 - 960
960 - 1200
1200 - 1440
1440 - 1680
1680 - 1920
1920 - 2160
2160 - 2400
0
30
60 Meters
Fire head front location
1-min interval
EFNCN-2008-Freiburg


Rate of spread
Rate of spread (sec)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
20 - 22
22 - 24
24 - 26
26 - 28
28 - 30
30 +
0 30 60 Meters
Fire head front location
1-min interval
EFNCN-2008-Freiburg


Histogram of Rates of Spread
Pixel numbers
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 4 6.5 8 12 16 20 24 28
Rate of spread range by 2 m/min classes
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
20 - 22
22 - 24
24 - 26
26 - 28
28 - 30
30 +
Rate-of-spread timer average
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Established Relationship Between Total FRE vs. fuel consumption

For each pixel:

Fire Radiation Energy (FRE) $E = \varepsilon \bullet \sigma \bullet T^4$ $(kW \cdot m^{-2})$

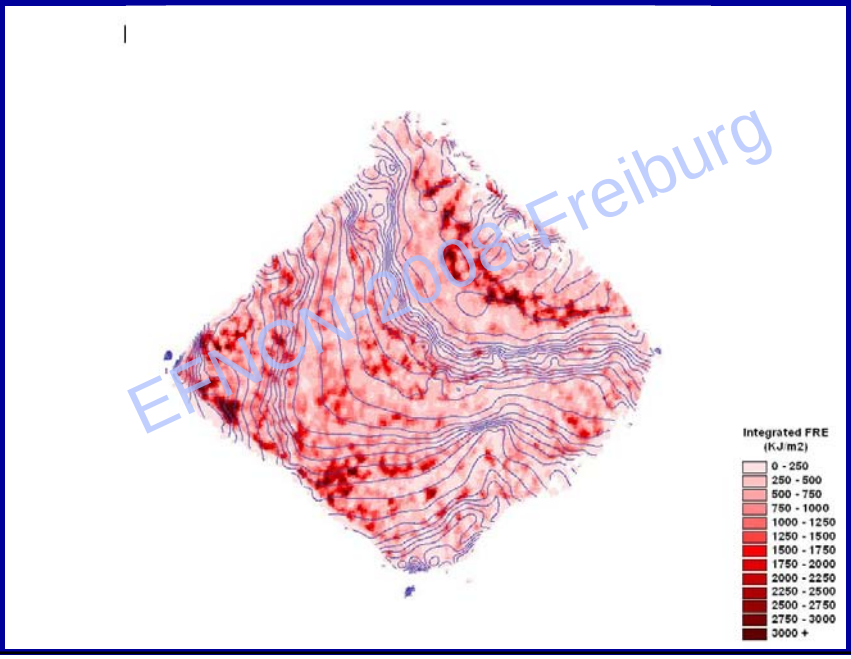
Total time-integrated FRE $J = \int E \bullet dt$ $(kJ \cdot m^{-2})$

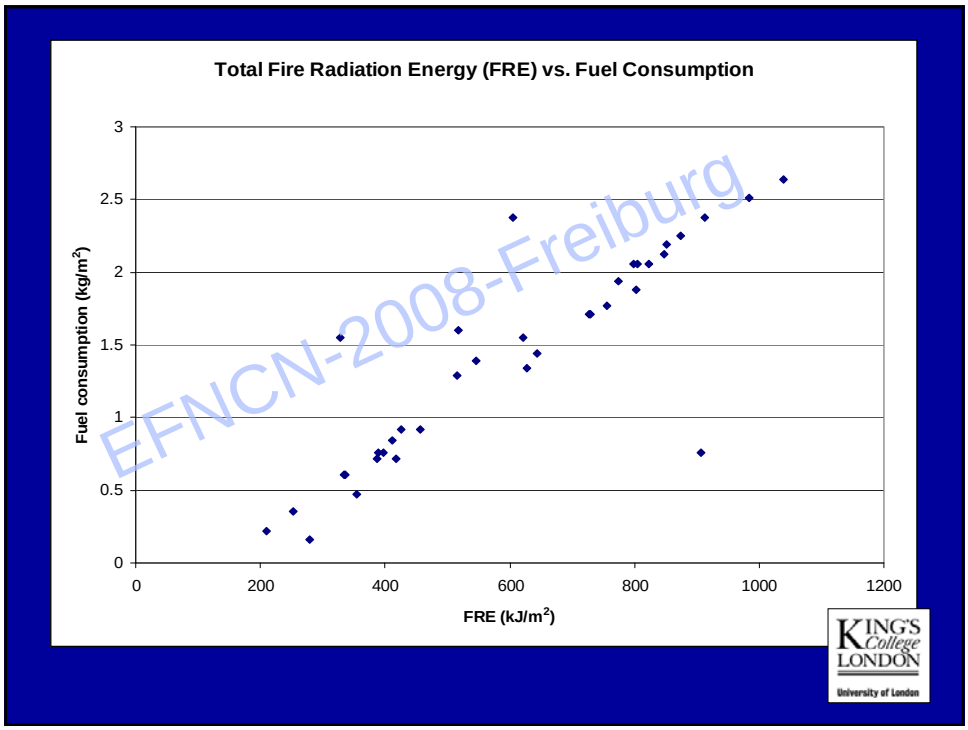
Digital integrated to simplify compute FRE:

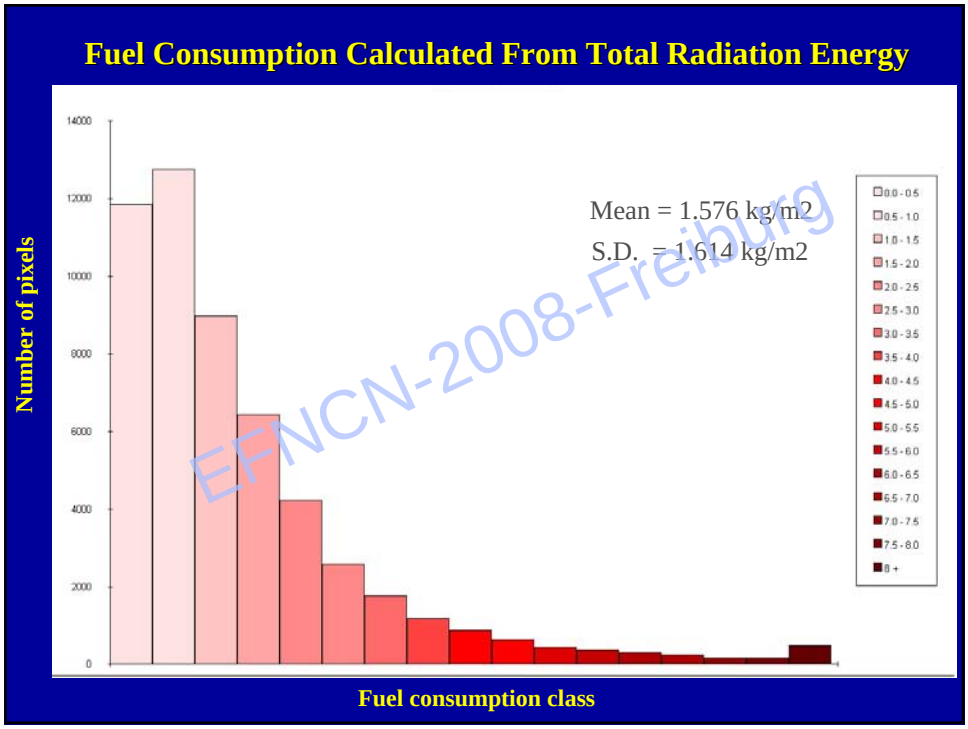
$$FRE = \sum_{n=2n}^{N} (E_n - E_1) \bullet (T_n - T_{n-1}) \qquad (kJ\ m^{-2})$$

E_1 – Background FRP
E_n – n^{th} image
N – Total of 41 images
Tn – Time of image n

Total Fire Radiant Energy




Total Fire Radiation Energy (FRE) vs. Fuel Consumption
Fuel consumption (kg/m2)
FRE (kJ/m2)
0
0.5
1
1.5
2
2.5
3
0
200
400
600
800
1000
1200
EFNCN-2008-Freiburg
KING'S College LONDON
University of London


Fuel Consumption Calculated From Total Radiation Energy
Number of pixels
Fuel consumption class
Mean = 1.576 kg/m2
S.D. = 1.614 kg/m2
EFNCN-2008-Freiburg
0
2000
4000
6000
8000
10000
12000
14000

Fuel and Fire Behavior Database

Fire	Date	Down woody	Litter	Forest floor	Crown fuel	burn (cm)	spread (m/min)	intensity (kW/m)
Yartsev site								
2	19/06/2001	0.034	0.098	1.194	0.000	4.4	4.9	2140
3a	24/07/2001	-	-	-	-	nd	0.6	183
3b	26/03/2001	0.028	0.185	0.719	0.000	3.3	2.5	1156
4	30/07/2001	0.252	0.156	0.965	0.000	3.9	1.4	587
6	30/06/2001	0.062	0.181	1.009	0.000	4.0	5.9	2473
13	26/07/2000	0.400	0.294	1.341	0.000	4.7	2.0	1067
14	18/07/2000	0.438	0.255	2.311	0.000	6.4	9.0	9018
19	28/07/2001	0.055	0.178	0.798	0.000	3.5	2.9	1016
20	25/07/2002	0.170	0.111	1.054	0.000	4.1	5.0	2200
21	26/07/2002	0.134	0.110	2.123	0.000	6.1	5.2	3987
21P	26/07/2002	0.077	0.110	2.123	0.000	6.1	-	-
Govorkova site								
1	18/06/2002	0.192	0.159	1.140	0.000	4.6	6.5	3195
2C	19/06/2002	0.221	0.109	1.826	0.480	5.6	26.7	23824
2NC	19/06/2002	0.221	0.109	1.826	0.000	5.6	6.8	4876

Model Correlation

Dependent variable	Independent variable*	Correlation (r)
Forest floor consumption	DMC	0.94
Carbon release	DMC	0.94
Depth of burn	DMC	0.88
Rate of spread	ISI	0.89
Fireline intensity	FWI	0.93

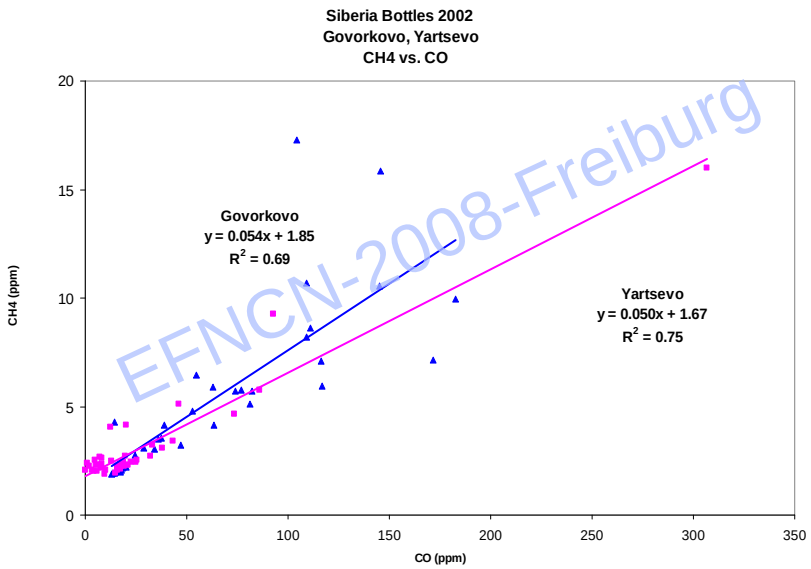
* Fuel moisture codes and fire behavior indices of the Canadian Forest Fire Weather Index System.

Emission Sampling

Russian and USFS ground teams

Aerial sampling

Carbon Emission



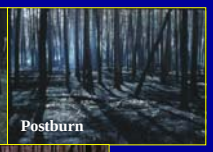
Particulate Emission Results

	Element															
	C0	K	Ca	Ti	Cr	Mn	Fe	Co	Zn	As	Se	Br	Rb	Sr	Zr	Mo
FS mean ($\mu g/m^3$)	50300	268	86	4.6	2.4	5.9	18.3	0.18	3.3	0.16	0.06	2.3	1.1	0.13	0.04	0.09
SD	42500	248	70	7	3.2	6.1	13	0.37	4.1	0.29	0.1	4.4	1.2	0.15	0.1	0.19
SE	7800	45	13	1.3	0.6	1.1	2.5	0.07	0.8	0.06	0.02	0.8	0.2	0.03	0.02	0.03
EMV	-	14.6	4.6	0.25	0.13	0.32	1	0.01	0.18	0.0087	0.0033	0.13	0.06	0.007	0.0021	0.005
RMV	-	0.58	0.55	0.11	0.0023	0.017	1	0.0005	0.002	0.00012	0.00002	0.0007	0.004	0.001	0.0045	0.0001
EMV/RMV	-	25	8	2	56	19	1	20	90	73	165	185	15	7	0.5	50

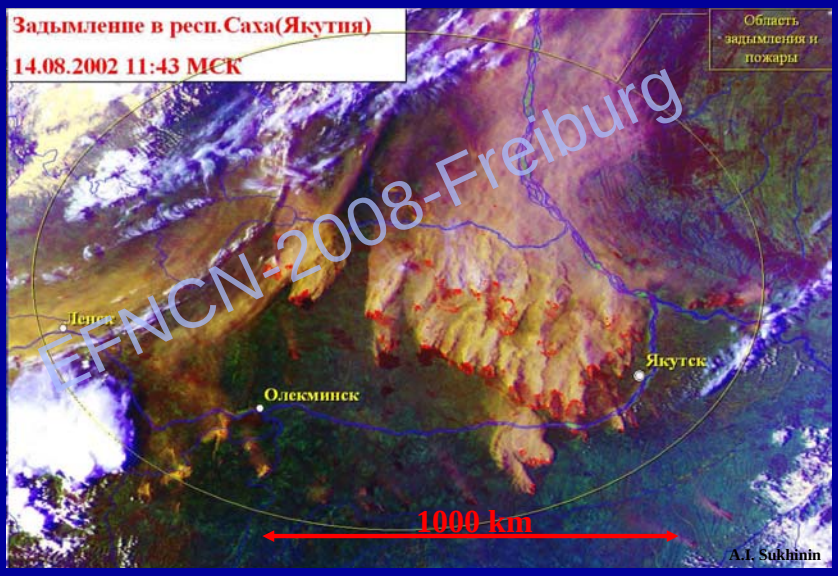
FS – Filter sample
EMV – Experimental mean value
RMV – Reference mean value
EMV/RMV - Experimental reference ratio

Fire Effect - Ecosystem Functioning

- Fire regimes
- Tree mortality
- Forest regeneration
- Ground vegetation
- Wildlife
- Soil chemistry
- Soil microflora
- Soil fauna
- Soil respiration



Remote-sensing Observations



Fire activity during the 2002 fire season in the Yakutia Region as depicted by NOAA AVHRR (14 August 2002)