

Wildfire Impacts on Carbon Stocks and Exchanges in Forests of Central Siberia: Quantifying Effects of Fire Intensity, Fire Severity, and Burning Conditions

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Additional collaborators:**Russian Collaborators**

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This research addresses needs expressed in the topic area of “Regional Studies to Reduce Major Uncertainties About the Carbon Cycle” in Eurasia. The principal investigator (S.G. Conard) along with the co-investigators (W.M. Hao, G.A. Ivanova, D.J. McRae, and A.I. Sukhinin) and other key collaborators (such as D.R. Cahoon, K.P. Koutsenogii, and A.J. Soja) have conducted successful research programs together in this region previously, including a project funded under NASA NRA-99-OES-06.

A 3-prong research approach is being undertaken combining multi-scale satellite, aerial, and empirical ground measurements to support validation and extend the accuracy and capability of remote sensing to quantify and monitor the role of wildland fires in carbon cycling in the forests of Siberia. Emphasis has been placed on Russian boreal forests since: (1) they contain about 25% of the world’s terrestrial biomass storage, and (2) have an active annual wildfire load (~20+ million ha in 2003; 10-15 million ha in more typical years). Increased wildfire activity that has been predicted in response to changing climate has potential to significantly affect the carbon storage capacity of Siberian forests.

The major objective of the proposed research is to combine data from ground and aerial sampling of experimental burns, wildfires, and other disturbances with medium-resolution (15-120 m) and 1-km resolution satellite data and empirically derived models to develop validated estimates of fire areas, fire severity, emissions, and the impact of fire on carbon balance for key forest types of central Siberia. This project continues to build on our past research on fire effects in Scotch pine forests by initiating similar research in larch forests.

The proposed research will result in a better ability to accurately determine the spatial and temporal distribution and environmental impacts of wildfire across Siberia using remote sensing. Because of the variability in fire behavior caused by different fuel characteristics and burning conditions, we will validate procedures for assessing fire severity, which has a direct correlation with the amount of carbon emissions and with tree mortality. Results will make it possible to better inventory changes in land cover caused by fires. This study will provide important information for developing recommendations on management of biomass, fire, and fire regimes to reduce CO₂ and CH₄ emissions, to enhance carbon storage and sustainable forest management, and to minimize negative impacts of fire on global environment.

Approximately 6-12 wildfire sites per year are being selected for ground validation sampling of fire severity and vegetation characteristics in conjunction with evaluation of satellite data. Sites are being selected to represent a range of burn severity and fireline intensity characteristics, with a focus on *Larix* (larch) and *Pinus sylvestris* (Scots pine) forests. For each site, scaling up from the ground to the coarser resolution satellite data (AVHRR and MODIS) will be employing higher-resolution satellite data. Ground measurements include pre- and postfire evaluation of the vegetation reflectance characteristics for areas of different severity

fires, and the state of the forest cover will be characterized in terms of death of trees or needles and dryness or moisture stress of live crowns. The ground sites will be selected based on aerial reconnaissance and discussions with Avialesookhrana personnel and on availability of clear-sky imagery before, during, and after the fires.

Keywords: 1) Research Fields: biomass burning, carbon cycle, fire ecology, land cover classification, product validation; 2) Geographic Area/Biome: boreal forest, Russia; 3) Remote Sensing: aerial photography, AVHRR, MODIS, LANDSAT, thermal IR; 4) Methods/scales: GIS, in-situ data, local scale, regional scale.

Questions, Goals, and Approaches

NASA ESE Scientific Questions addressed: a) What are the changes in land cover resulting from fire (monitoring of fire area and severity from aircraft and satellite)? b) What are the causes of this land cover change (how does fire severity affect land cover change)? c) What are the consequences of fire-induced land-cover change on carbon cycling and ecosystem processes?

While this research does not include a specific social science component, it does address issues critical to resource-management decision-making; it might be noted that much of the success of accomplishing this type of research in Russia rests as much on understanding and working with social customs/habits and administrative structures of the country and the regions as on the quality of scientific collaboration! This takes 10-20% of our time in dealing with these necessary aspects of the work. In terms of research themes, the interest is divided into the following interest areas: Carbon: 50%; Nutrients: 5%; GOF: 25%; other (including fire behavior, ecosystem effects other than carbon, water, or nutrients): 20%.

Overall Research Goals and Approach:

RESEARCH GOALS

The major objective of the proposed research is to combine data from ground and air sampling of experimental burns, wildfires, and other disturbances with medium-resolution (15-120 m) and 1-km resolution satellite data and empirically derived models to develop validated estimates of fire areas, fire severity, emissions, and the impact of fire on carbon balance for key forest types of central Siberia. This project will continue to build on past research on fire effects in Scots pine forests by initiating similar research in larch forests.

- Continue data analysis, long-term postfire data collection, and model development on Scotch pine sites for refining estimates of effects of fire severity on carbon cycle, direct fire emissions, and forest recovery and productivity.
- Continue to develop models relating fire behavior, fire weather, and fuel condition at the time of burning to carbon emissions, energy release, and other ecosystem impacts.
- Build on past work on Scots pine forests by implementing similar approaches to those used successfully in the past to study effects of fire on carbon cycle in larch forest types. These two forest types make up 58 % of the area of forest in the Asian part of Russia representing the two main types with mixed severity fire regimes.
- Quantitatively characterize the active fire detection threshold, and fire mapping/monitoring capability of MODIS by verifying the point spread function for the fire detection channels using a variety of fire conditions. Results will be compared with the capabilities of NOAA/AVHRR monitoring.
- Evaluate the potential for estimating emissions directly from satellite infrared channels through relationships between energy release from fire and fire emissions.

RESEARCH APPROACH

Combine multi-scale satellite, aerial, and empirical ground measurements to support validation and extend the accuracy and capability of remote-sensing to quantify and monitor the role of wildland fires in carbon cycling in the forests of Siberia. We are finishing emphasizing completion of our 5-year postfire monitoring and data analysis activities for our work on Scotch pine, while developing new study areas and shifting the focus of remote sensing activities to larch forests.

- Use AVHRR, MODIS and other higher-resolution satellite data, combined with ground data, to continue to develop and test methods for estimating the spatial extent of fires, and to develop and validate methods to estimate spatial patterns of burn severity for pine and larch forests in central Siberia.
- Use ground data from replicated experimental fires to refine estimates of impacts of fire severity and seasonality on fire behavior, fire emissions, biogenic emissions, carbon storage, fuel dynamics, and ecosystem damage and recovery.
- Refine regional estimates of fire impacts on fuel dynamics, ecosystem processes, and carbon (e.g., CO₂, CH₄) and trace gases by linking models developed from experimental data to spatial estimates of extent, intensity, and timing of fires.

PLAN OF WORK AND ACCOMPLISHMENTS

Winter/Spring 2005-6

- ◆ Analyze summer 2005 field data and revise methods as necessary; evaluate performance of fire behavior models; continue development and testing of algorithms. **Completed.**
- ◆ Russian colleagues work with Krasnoyarsk Region and Leshoz personnel to identify an additional study site to be established in 2006 for experimental burns in larch forest in the Krasnoyarsk Region. **Completed.** Several sites were pre-selected in the spring to be fully evaluated in the summer when the North American team was present.
- ◆ Plan work for summer 2006 and work on publications via e-mail. **Completed.** Plans were made to continue our successful burning program.
- ◆ Begin writing first drafts for the IJWF special issue. Russian papers will be translated to English. **Partially completed.** First drafts of seven Russian papers have been completed.
- ◆ Participate in NEESPI science team meeting. **Completed.** Conard, Ivanova, and Sukhinin attended the February meeting in Vienna. Conard attended the April 2006 LCLUC meeting.

Summer 2006

- ◆ Conduct burns on site established in 2005 in Nevinsky Leshoz; complete prefire, during fire, and immediate postfire sampling. **Partially completed.** Despite an unusually severe fire season in the Angara Region, three burns were initiated on our plots. One of these (Plot 2) was severe enough to kill all trees on the plot. The other two burns provided data on ignitability and thresholds of fire spread at lower fire-danger levels.
- ◆ Install plots and collect prefire data for new larch site. Conduct burn and obtain data during and after fires on 1-2 plots if possible. **Partially completed.** We are waiting for approval to use a new site selected in the Nevinsky Leshoz. The ground fuels of feather moss are different from our 2005 plots, which have a litter ground fuel.
- ◆ Select additional wildfires for remote-sensing and ground sampling, with a focus on larch sites; overfly fires with IR and visible instruments as feasible; obtain intermediate resolution satellite data and ground truth data. **Completed.** Ground sampling was done on larch sites in the Tuva Region. Six active wildfires were aerially monitored with IR.
- ◆ Complete post-fire sampling as scheduled on the Scotch pine sites burned in 2002 and 2003 (and unburned controls) in Boguchany area (Khreptova and Govorkova). **Completed.** Third and fourth year assessments were completed at each site, respectively.
- ◆ Participate in International Boreal Forest Research Association meeting in Umea, Sweden and Climate Change meeting in Yekaterinburg as feasible. **Completed.** Conard and McRae attended the Sweden conference, while McRae and Kukavskaja attended the Yekaterinburg conference.

Fall/Winter 2006-7

- ◆ Analyze summer 2006 field data; continue to test and refine fire behavior models; begin model development for emissions relationships to fuels and severity. **On-going.** Data from the 2006 field season are currently being analyzed.
- ◆ Complete review of papers for IJWF special issue. **On-going.** Second drafts are being finished for Russian authors after the initial reviews. Several first drafts are still anticipated. It is our hope to have all papers completed by fall 2007 for forwarding to the *International Journal of Wildland Fire* as a special issue volume.
- ◆ Begin final planning and preparation for conducting 2007 experiments, involving a PI meeting in Russia in February 2007.
- ◆ Obtain all necessary permits for conducting the 2007 experiments (e.g., land, burning, aerial, etc.).
- ◆ Purchase and shipment of any equipment to Russia in sufficient time to clear Russian customs.
- ◆ Participate in NEESPI and LCLUC science team meetings.

Summer 2007

- Conduct final burns at our 2005 Nevinsky site (1-2 plots in July); complete prefire, during fire, and immediate postfire sampling.
- Install plots and collect prefire data for our new larch/ feather moss site. Conduct burn and obtain data during and after fires on 1-2 plots if possible.

- Select additional wildfires for remote-sensing and ground sampling, with a focus on larch sites; aerial monitor fires with IR and visible instruments as feasible; obtain intermediate resolution satellite data and ground truth data.
- Complete post-fire sampling as scheduled on the Scots pine and larch burn sites.

HIGHLIGHTS

- **Three burns (Figure 1) were conducted during in the summer of 2006 (Nevinsky leshoz) giving us our first experimental fire data in Russian larch forests.** Larch occupies 263 million ha (46 % of the forest cover) in Siberia making it important to study related to its fire regimes. Given the large fire problem in the Angara Region this past summer (i.e., high fire danger and limited suppression forces), we feel fortunate to have completed these burns. Standard data on fuels, stand characteristics, fire weather, fire behavior, and fuel consumption were conducted and are being analysed.
- **Emission samples were collected and analyzed** from two fires at the Nevinsky site. Emission factors for major carbon compounds in smoke were determined for these fires (Table 1). Both fires had relatively low combustion efficiency (MCE) values of 0.85 and 0.84. The relationships between concentrations of methane (Figure 2), ethylene, and propylene and CO concentrations in smoke for both of these fires all had r^2 values >0.99 .
- **Prefire and immediate post-fire soil respiration measurements (Figure 3)** showed decreased respiration similar to that observed in our previous work on Scots pine forests in the same region. While these results are preliminary, they suggest that the substantial reduction in soil respiration after fires that we observed earlier on three Scots pine sites may also occur on the moister larch sites, and may help to balance out some of the direct wildfire emissions. Soil respiration on previously burned Scots pine sites (Figure 4) appears to take several years to recover to the levels in unburned controls.
- **A second study site has been located in larch-dominated forest.** This site has the potential to have four 1-ha plots. Unlike our first larch site, which had a litter ground fuel, this surface fuels on the second site are dominated by a feather moss ground cover. The two ground fuel types will allow us to document the variability of fire behavior on larch sites.
- **Regional observations of burned area (from satellite) and calculations of seasonal changes in fire hazard were completed for the 2006 season.** A draft report on these data shows that the 2006 fire season in the Krasnoyarsk region was the most severe in eleven years of observation, with a burned area nearly twice as large as recorded previously (Figure 5). Wildfires were especially widespread in an area near Boguchani along the Angara River, near where we are conducting our field experiments (Figure 6). With essentially no rain for June and July, fire hazard indices were near record highs for several weeks (Figure 7, 8).
- **Using NOAA AVHRR satellite imagery, that has been archived since 1979 when the**

first polar-orbiting satellites were launched, computer programs have been written that can geocorrect, compile, store and analyze large numbers of satellite images to produce annual burn area estimates for Russia. The 1985-1987 period (i.e., a period of high fire activity in Russia) has been used to develop and test the analytical procedures. Once all analysis is complete, burned area figures will be derived for the years 1981-1995 to augment the estimates that we have already for the post-1996 period using remote-sensing estimates compiled annually by Dr. Sukhinin at the Sukachev Institute. Such data are crucial in understanding past burn amounts, as official estimates for Russia have notoriously underestimated actual burn areas.

- **Hourly weather data from Russia for the post-1980 period is being used to calculate all components of the Canadian Forest Fire Danger Rating System for any time period (weekly, monthly etc. – see Figure 9).** Raw weather data from the NOAA National Climatic Data Center has been downloaded and checked for accuracy. Figures 10 and 11 illustrate the relationship between the Canadian Fire Weather Index (CWI) and actual areas burned for an area of central Siberia in June 2003. Upon completion, this 26-year database (1981-2006) will be analyzed to understand the trends in annual fire danger to better understand current impacts related to climate change. One of the many uses of this data will be to provide a surrogate measure of fire behavior during the periods of large fire activity between 1980 and 1994 as estimated from our remote-sensing efforts. This will be done by identifying times when aerosol concentrations are high by analyzing Tropospheric Ozone Measuring Satellite (TOMS) data. Smoke from large forest fires is quite visible using this product, and data are available daily.
- **A series of experimental test fires were conducted to investigate the potential of infrared technology for remotely estimating fuel consumption using satellite monitoring.** This approach is based on the theoretical relationship between radiant energy (as measured by the camera) and biomass consumption (energy released by the fuel). Using a truck boom bucket (Fig. 12), middle- and long-range infrared cameras were positioned directly over the fires, which were conducted on a computerized weighing platform (Figure 13, left). Initial results indicated a good correlation between energy and consumption regardless of fuel type (Figure 13, right). These results could lead to the use of satellite monitoring for measuring carbon emissions resulting from biomass burning.
- **Post-fire sampling was continued on previously burned sites.** Third-year and fourth-year sampling was carried out on plots burned in 2002 and 2003. We have developed a timetable for periodic sampling of past burns at decreasing frequency. This is designed to allow us to manage limited resources so that we can complete necessary post-burn sampling as well as to carry out work on new larch sites.
- **A field team continued investigating wildfire severity and vegetation characteristics on fires monitored from satellite.** The team concentrated for the first time this year outside of the Angara Region focusing on larch-dominated forests in the Tuva Region. This new forest type will assist in understanding the relationships between burn severity on wildfires and effects, and the methodology to recognize these differences on satellite imagery. Twenty-six test plots were established in intensive fires which occurred in 2002.

- **A second field team verified burning indexes and identification of different forest species**, to assist in classification using multi-spectral data from the Constellation Observing System for Meteorology, Ionosphere and Climate (Cosmic) satellite, near the Zotino Tall Tower Observation Facility.
- **We used a new middle-range infrared camera to obtaining aircraft-based images on several wildfires** this past summer. Because of previous problems with bringing cameras into the country and with image quality from a previous camera obtained in Russia, we leased a camera from Tomsk University for this year's flights. We are still attempting to have the images officially released for our use, so we are unable at this time to confirm the camera resolution and usefulness of the images. Based on previous experience, release of the data for scientific use can take up to a year.
- **Four Russian scientists working on our project have received their senior scientist classification during the last year.** One of these scientists has now been assigned as chief of the Sukachev Institute's Fire Laboratory.
- **A special issue of International Journal of Wildland Fire is being developed.** Seven Russian draft papers have already been written and reviewed internally and are being revised by their authors.
- **Conard and McRae organized and chaired a session on "Fire Effects and Fire/Climate Interactions in Boreal Forests"** at The Third International Fire Ecology and Management Congress in San Diego, California (November, 2006).
- **Scientists participated in several meetings in Russia, Australia, and the US:**
 - NEESPI meeting, Vienna, Austria (February 2006)
 - International Congress Geo-Siberia-2006, Novosibirsk, Russia (April 2006).
 - International scientific conference on "Ecology and biology of soils: diagnostics and indication problems," Rostov-on-Don, Russia (April 2006).
 - Canadian Meteorological and Oceanic Society Congress, Toronto, Ontario, Canada (May 2006).
 - "Climate Changes and their Impact on Boreal and Temperate Forests," Ekaterinburg, Russia (June 2006).
 - Workshop at the Forest Research Institute Warsaw, Poland (July 2006).
 - International Boreal Forest Research Association Conference, Umea, Sweden (August 2006).
 - NEESPI's "International Symposium: Environmental change in Siberia: Insights from Earth Observation and modeling," The University of Leicester, Leicester, UK (September 2006).
 - "Tropical Rain Forest and Boreal Forest Disturbance and Their Affects on Global Warming," University of Palangka Raya, Palangka Raya, Indonesia (September 2006).
 - 3rd International Fire Ecology and Management Congress, San Diego, CA

(November 2006).

CHALLENGES

While in general our collaboration with Russian investigators has continued to be strong, there are ongoing problems with securing permission for study sites due to changes in forest regulation for land use and tenure. We are also trying to understand the implication if the mandate for forest fire fighting is transferred to the regions in 2007. This increases the difficulty of finding appropriate sites for our work and conducting empirical burns for gathering data. However, we are optimistic in being able to continue our successful field program through expanded efforts.

As regulations over the use of aircraft and infrared remote sensing become stricter, we have abandoned attempts to bring infra-red cameras into the country for our work. It now takes at least 6 months to clear a camera for use in Russia. The camera we used in 2003, which was manufactured in China, turned out to have inadequate thermal amplitude for our needs, and to have numerous problems with software, despite having appropriate specifications on paper. Therefore, we will work with a Russian company, as we did in 2002, to lease a camera for 4-6 weeks during the fire season. We anticipate that this will cost about \$10,000 per 2 weeks, but it appears to be the only feasible option - and this is a critical component of our project.

Transferring funds to Russia remains a challenge, as according to a new law the Russian banks can no longer accept checks for institutional accounts. We learned this last year after we had already prepared a check for the fund transfer. This caused considerable delays in getting funds to our collaborators. Fortunately, after several years' hiatus the FS is again able to do international wire transfers.

Despite the inherent difficulties of working in Russia, this project continues to make good progress. We continue to develop perhaps the most comprehensive integrated data set on fire emissions, fire behavior, and ecosystem effects ever collected in the boreal Eurasian zone. We look forward to producing a special journal issue on our work in Scots pine.

We are excited to be able to begin expanding our data gathering to the larch forests, which are the most extensive forest types in Russia. Through this research we will increase the understanding of landscape extent and severity of fires and of the effects of fire behavior and intensity on carbon release and storage--including impacts on air chemistry, soil respiration, and vegetation dynamics and structure.

Although a seminar on writing scientific papers was held at the Sukachev Institute in 2005, we are experiencing difficulties in having peer-review ready papers written by our Russian colleagues for our Special Issue with the *International Journal of Wildland Fire*. The review process within our own group is very time consuming due to difficulties in translating technical terminology, cultural differences in writing styles (e.g., Russian papers tend to be redundant, yet often omit important details, and descriptions of methods may be inadequate). This has slowed our progress, but we are hoping still to have the Special Issue ready by

summer 2007 for forwarding to the journal.

The Sukachev Institute, as are other Russian Academy of Sciences Institutes, is facing downsizing of staff. Recently, we lost our project translator. Morale is poor for PhD candidates, as there are no prospects for permanent employment.

New Publications for 2006 (project authors in bold):

- Bogorodskaya A.V.** 2006. Pyrogenic factor influence on structure and ecological functions of soil microbial cenoses of the Lower Angara Region pine stands. *Investigations in Russia Internet Journal* 137:1277-1288. Available on Internet: <http://zhurnal.ape.relarn.ru/articles/2006/137.pdf>. (in Russian)
- Bogorodskaya A.V. and Sorokin N.D.** 2006. Microbiological diagnostics of state of fire-changed soil in Lower Angara Region pine stands. *Soil Science* 10: 1258-1266.
- Buriak L.V., and **Ponomarev E.I.** 2006. Monitoring of disturbance territory using DMCII satellite data. *J. Geography and Natural Recourses*. (Submitted).
- Buriak L.V., **Ponomarev E.I.**, and Kalenskaya O.P. et. al. 2006. Monitoring of particularly protected territory (National Shushensky Pine Forest) using remote-sensing and forest inventory database. pp. 156-161 in *Proceeding of All Russian Conference on New Information Technologies in Complex Structures Investigation*. Tomsk State University Bulletin No. 18. (in Russian)
- Drobusheskaya O.V., and **Ponomarev E.I.** 2006. Phenological rhythms of light coniferous and dark coniferous Taiga in the Sayany Mountains using TERRA/MODIS data. *J. Botanic Investigations* 14: 35 – 38.
- Ivanov V.A., Ivanova G.A., and Kukavskaya E.A.** 2006. Possible ignition zone of surface fuels by current of lightning in forest. *Forestry* 5: 40-43.
- Kukavskaya E.A. and Ivanova G.A. 2006. Forest fire influence on biomass in central Siberian pine stands. *KrasSAU herald* 12: 156-162.
- Loupian, E.A., Mazurov, A.A., Flitman, E.V., Ershov,, D.V., Korovin, G.N., Novik, V.P., Abushenko, N.A., Altvntsev, D.A., Koshelev, V.V., Tashchilin, S.A., Tatarnikov, A.V., Csiszar, I., **Sukhinin A.I.**, Ponomarev, E.I., Afonin, S.V., Belov, V.V., Matvienko, G.G., and Loboda, T. 2006. Satellite monitoring of forest fires in Russia at federal and regional levels. *Mitigation and Adaptation Strategies for Global Change* 11: 113-145.
- M^cRae, D.J., S.G. Conard, G.A. Ivanova, A.I. Sukhinin, W.M. Hao, K.P. Koutzenogij, S.P. Baker, V.A. Ivanov, Y.N. Samsonov, T.V. Churkina, A.V. Ivanov, and T.W. Blake. 2006. “Fire regimes, variability in fire behavior, and fire effects on combustion and chemical and carbon emissions in Scotch pine forests of central Siberia.” *Mitigation*

and Adaptation Strategies for Global Change **11**: 45-76.

Nazimova D.I., Drobusheskaya O.V., and **Ponomarev E.I.** 2006. Natural resources potential estimation of mountain forests using remote-sensing data. pp.167-172 *in* All Russian Conference on Natural-Resources Potential Estimation of the Selenga River Basin Forests, Buriatya, Ulan-Ude.

Ponomarev E.I., Ivanov V.A., and Byčkov V.A. 2006. Large-area forest fires in the Eastern Siberia and their influence on process of local storm cloud formation. *Lešne Prace Badawcze* **4**: 19-28. (in Polish)

Ponomarev E.I., Ivanov V.A., and Korshunov N.A. 2006. Forecasting of fire danger estimation using ATOVS and lightning-distribution data. *J. Geography and Natural Resources* **1**: 147 – 150.

Ponomarev E.I., Sukhinin A.I., and McRae D.J. 2007. Daily weather fire danger mapping by means of satellite Data in Eastern Siberia *in* V International Conference on Forest Fire Research, Coimbra, Portugal, 2006. (Submitted)

Soja, A.J., Shugart, H.H., Sukhinin, A.I., Conard, S.G., and Stackhouse Jr., P.W. 2006. Satellite-derived mean fire return intervals as indicators of change in Siberia (1995–2002). *Mitigation and Adaptation Strategies for Global Change* **11**: 75-96.

Soja, A.J., Tchebakova, N.M., Sukhinin, A.I., French, N.H.F., Flannigan, M.D., Shugart, H.H., Stocks, B.J., Parfenova, E.I., and Chapin, T. 2006. Current Evidence of climate-induced boreal forest change. *Global and Planetary Change*. (Accepted)

Sukhinin A.I., Buriak L.V., and Ponomarev E.I. 2006. GIS and remote-sensing data for monitoring of forest disturbances in the Angara Region. pp. 179-185 *in* Proceeding of All Russian Conference on New Information Technologies in Complex Structures Investigation. Tomsk State University Bulletin No.18. (in Russian)

Sukhinin A.I., McRae D.J., Ponomarev E.I. 2006. GIS of wildfire danger evaluation and forecasting using remote-sensing data. pp. 126-134 *in* Proceeding of International Congress GEO-Siberia-2006, Siberian State Academy of Geodesy, Novosibirsk.

Valendik, E.N., **Sukhinin A.I.,** and Kosov I.V. 2006. Stability of coniferous forest to wildfires thermal influence. Krasnoyarsk, 96 p. (in Russian)

Patents

Shakhranian M.A., **Sukhinin A.I.,** Silkin A.V., Miskiv S.I., and **Ivanov V.V.** 2006. Multi-functional program for acquisition and processing of satellite data. SPACE-M2 Certificate of ROS Patent No. 2005612058.

Conference Presentations and Abstracts

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Figure 1. An example of mixed-wood larch fire behavior on our experimental sites in Nevinsky leshoz in central Siberia: On the left, a high-intensity surface fire (Plot 2) severe enough to cause tree mortality of all trees on the site, and on the right, the postfire site showing the complete mortality of all above-ground vegetation.

Date	----- Emission Factors (g/kg) -----							MCE
	CO	CO ₂	CH ₄	C ₂ H ₄	C ₂ H ₆	C ₃ H ₆	C ₃ H ₈	
Plot 2 7/23/06	173.9	1537	6.15	1.50	0.00	0.50	0.06	0.85
Plot 1 8/03/06	185.7	1493	12.48	2.31	1.11	1.08	0.18	0.84

Table 1. Emission factors and MCE (modified combustion efficiency) for the 2006 fires in a larch-mixed forest stand in Nevinsky leshoz. Given the higher global warming forcing coefficient of methane (CH₄), effective CO₂ equivalents for these fires would be increased by about 10 to 20 percent (100-year basis) to 25 to 50 percent (20-year basis) when methane emissions are included.

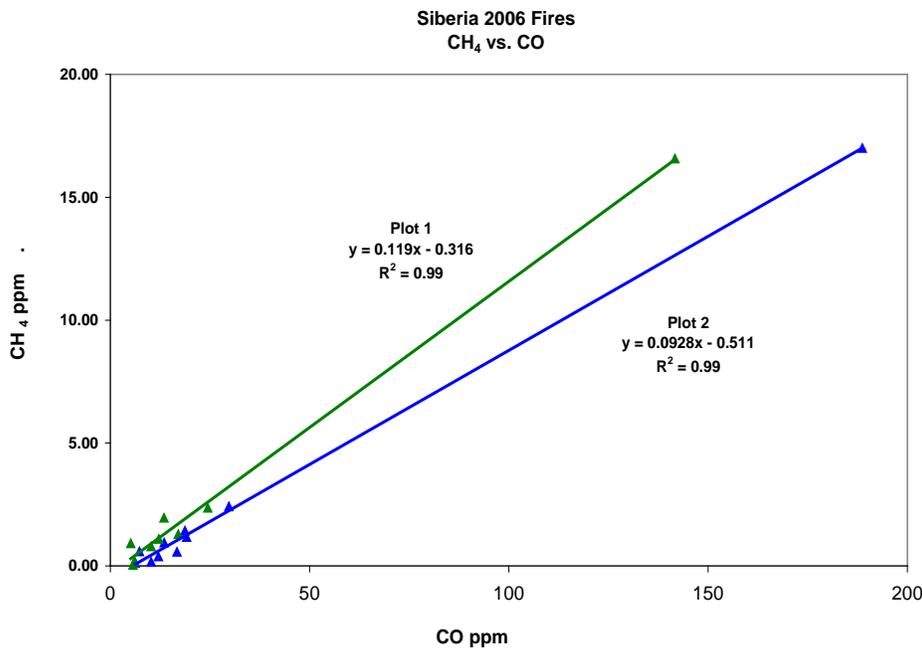


Figure 2. Emission factors for methane relative to carbon monoxide at two fires on the Nevinsky site in 2006. Note the higher relative emissions for the lower intensity fire on Plot 1. As noted in table 1, the combustion efficiency was relatively low for both fires.

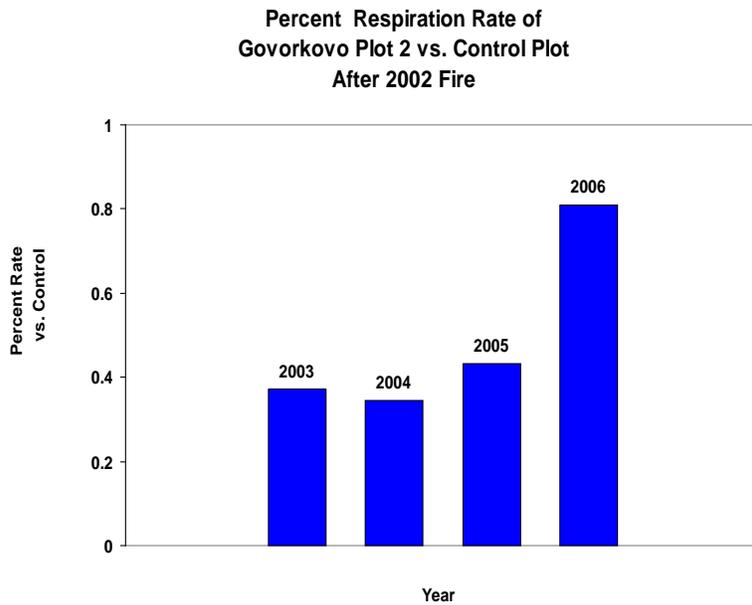


Figure 3. Soil respiration was re-measured at the Govorkovo plots in the summer of 2006. These plots were burned in 2002 and soil respiration has been measured annually since. The 2006 results showed a substantial recovery in soil respiration rate for plot 2, which had burned at relatively high intensity. The Govorkovo site will be measured again in 2007.

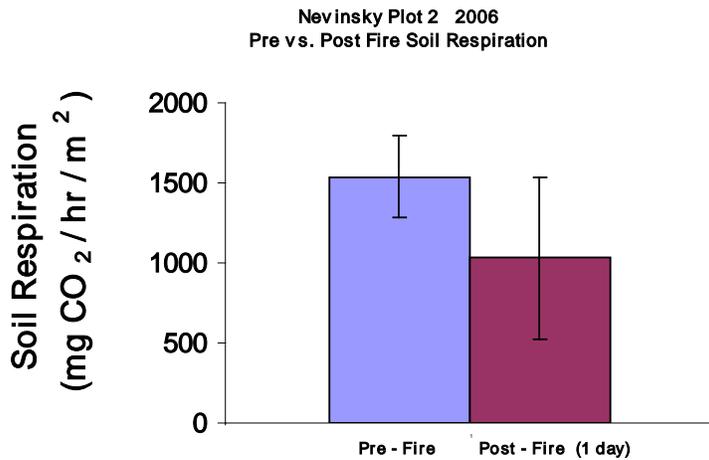


Figure 4. Soil respiration rates measured at Nevinsky plot 2 pre- and post fire. The post-fire soil respiration rate on the day after the plot 2 fire was reduced by approximately one third. While preliminary, these results are similar to those we have observed in earlier research on Scots pine site in the same region, giving us more confidence that we can develop relationships that reflect broad regional responses.

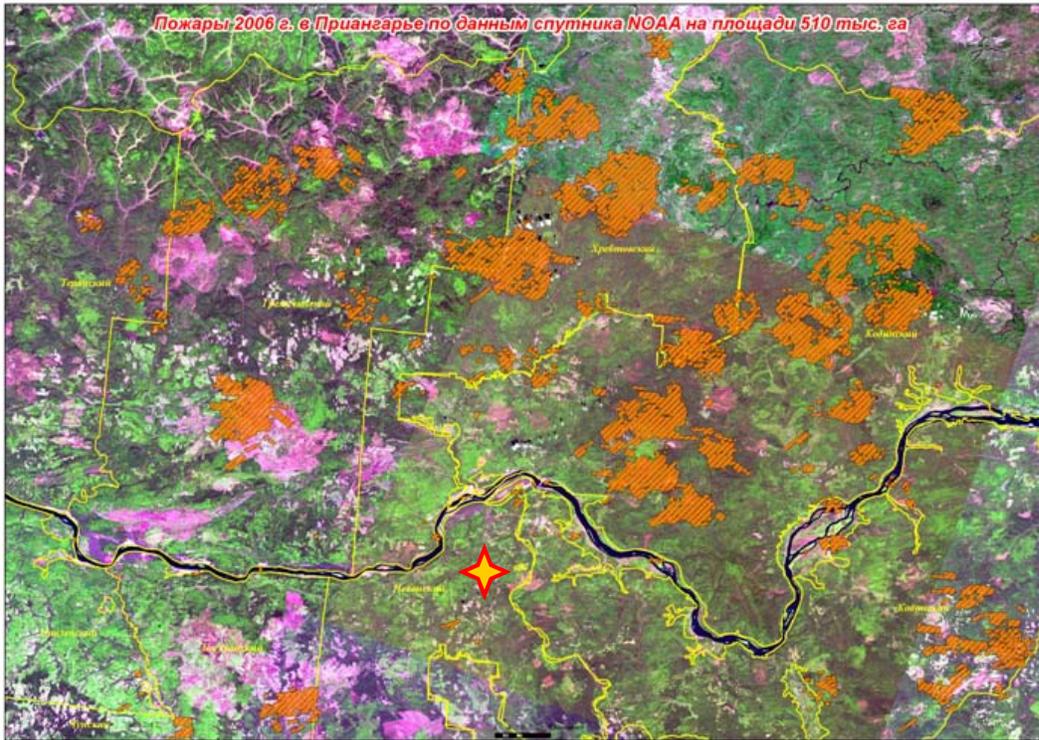


Figure 5. Fires near the Angara River in Krasnoyarsk Region of central Siberia, summer 2006. The total burned area in this image is 510,000 ha. The location of the study area where 2006 burns were conducted is indicated by the star.

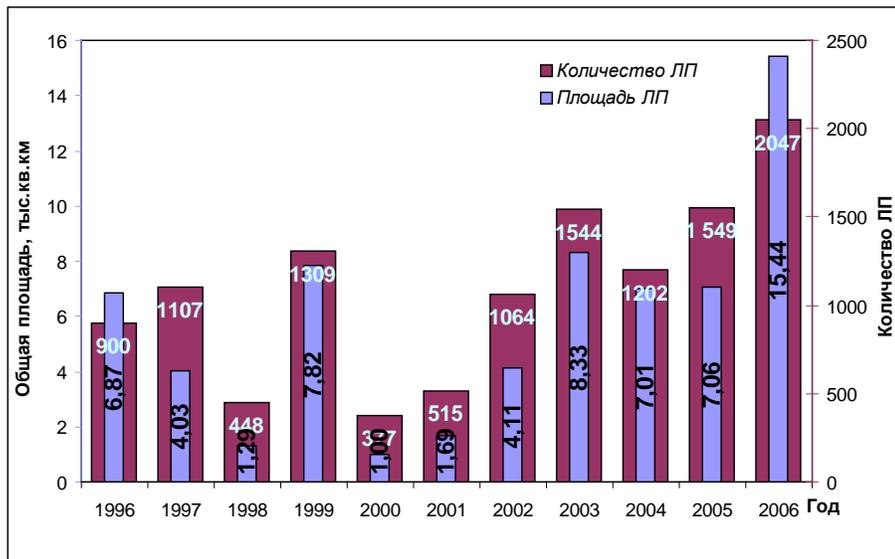


Figure 6. Summary of fire numbers (purple; right axis) and area burned in thousands of square kilometers (blue; left axis) in Krasnoyarsk region for the years 1996 – 2006.

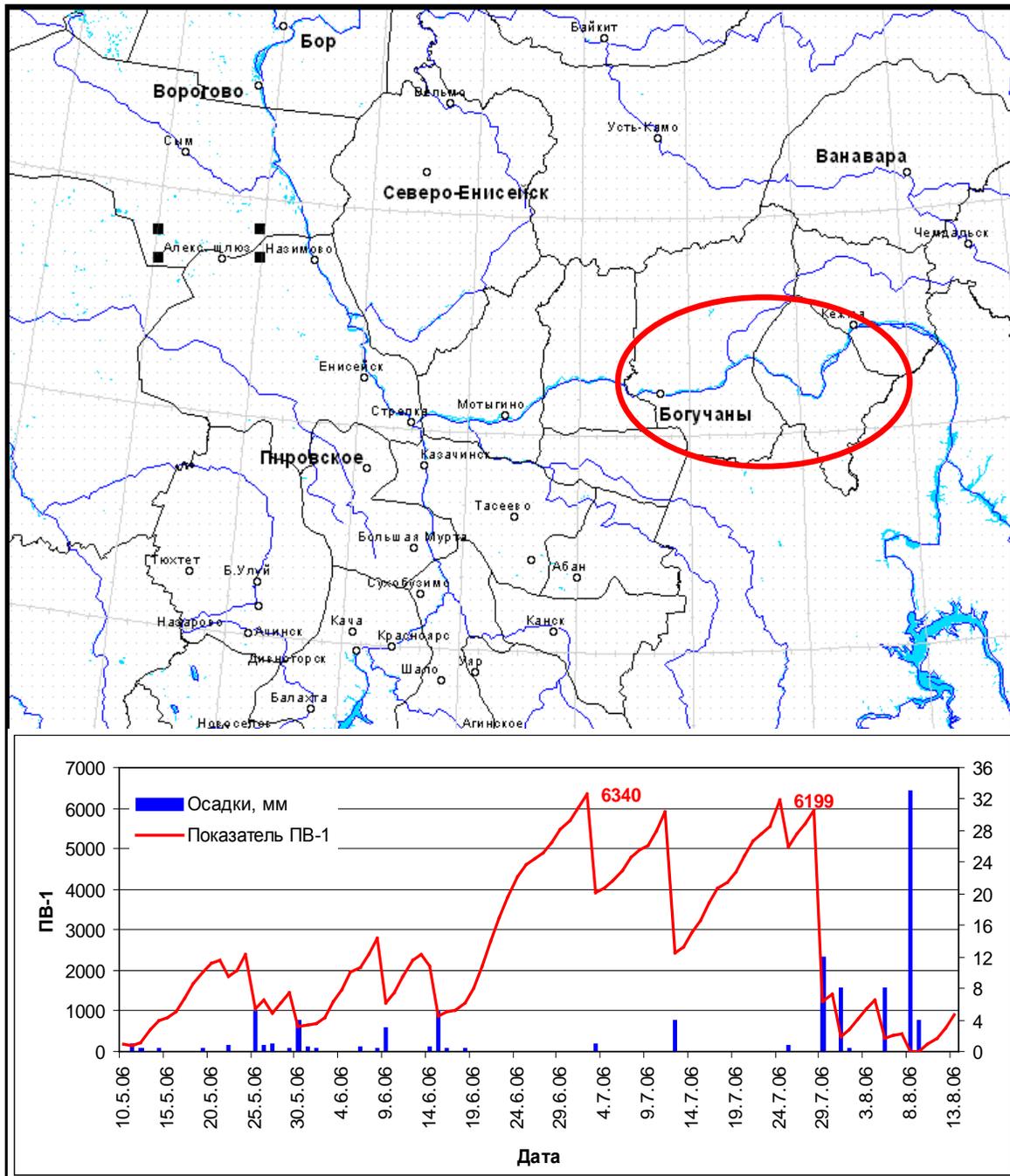


Figure 7. Seasonal changes in fire hazard index (red line) and rainfall (blue bars) for the Boguchani station near our Nevinsky leshoz, Govorkovo, and Khreptova study areas. Similar calculations have been made for numerous stations across central Siberia. Based on regressions developed for Scots pine sites, we can estimate, for example, that total fuel consumption for a fire on June 30 would be compared to for a fire burning on July 5, when the index was lower.

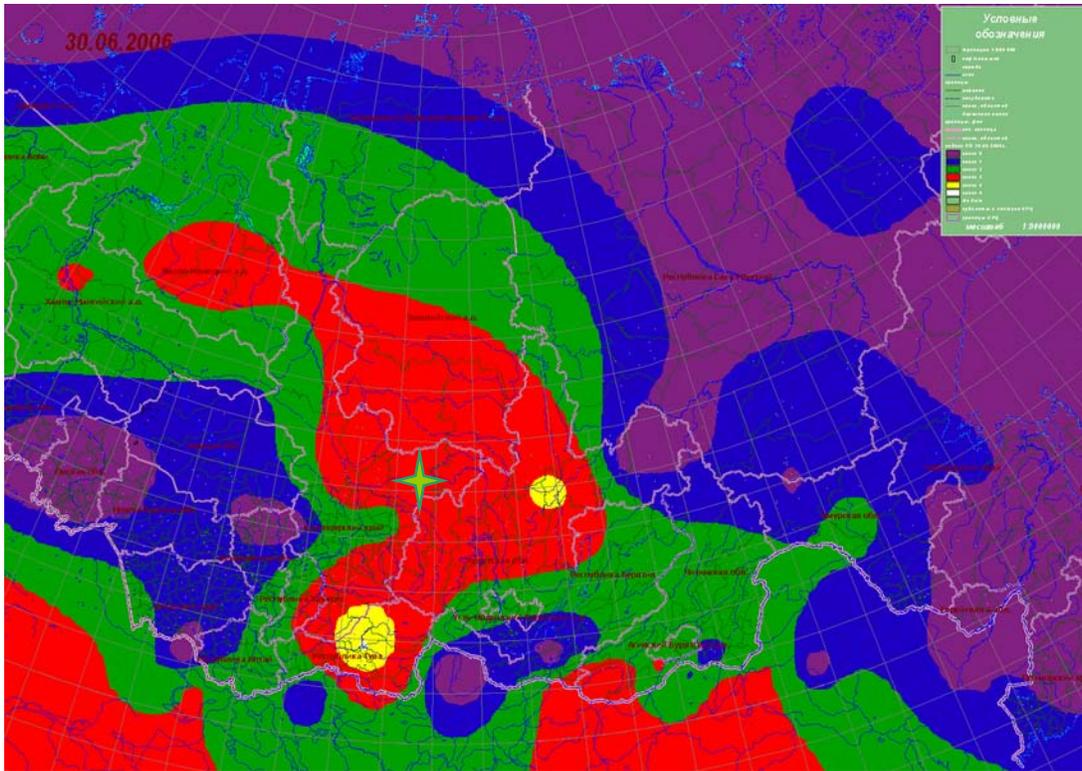


Figure 8. Fire weather index for central Russia, June 30, 2006. The large area of high fire hazard is centered on the Angara River region shown in Figure YY. Green star shows approximate location of our study site in Nevinsky leshoz. Data from Anatoly Sukhinin.

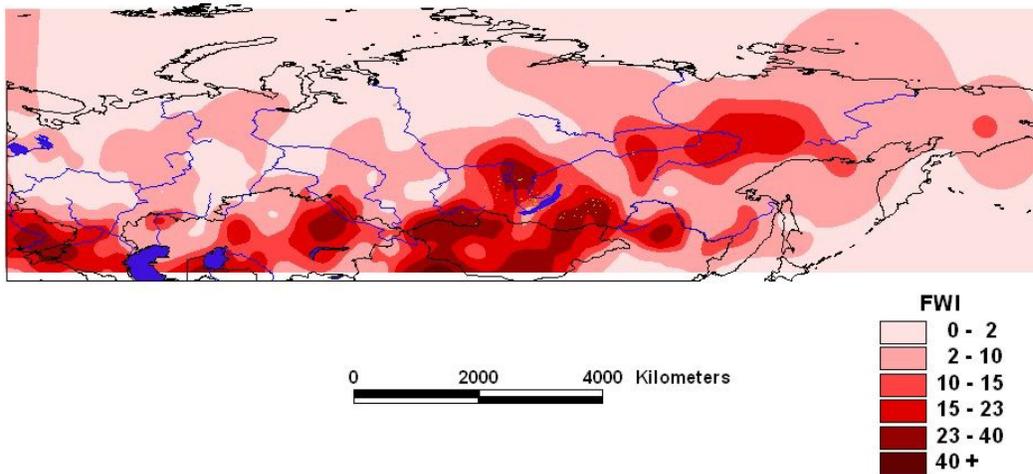


Figure 9. A contour map showing the distribution of the Fire Weather Index (FWI), a component of the Canadian Forest Fire Danger Rating System (CFFDRS) used as an indicator of potential fire intensity and fire danger, across Russia for 15 June 2003.

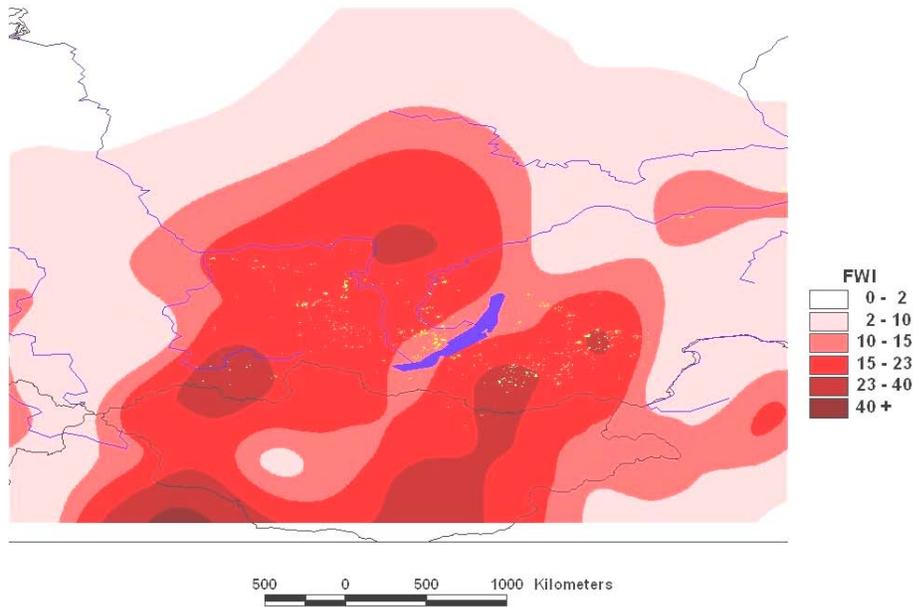


Figure 10. Distribution of the average Fire Weather Index (FWI) in central Siberia, 6-15 June 2003. Note how the location of fire hot spots, depicted in yellow (Sukachev Institute data), correlate well with the high FWI values found in this region. Lake Baikal is in the middle of the map.

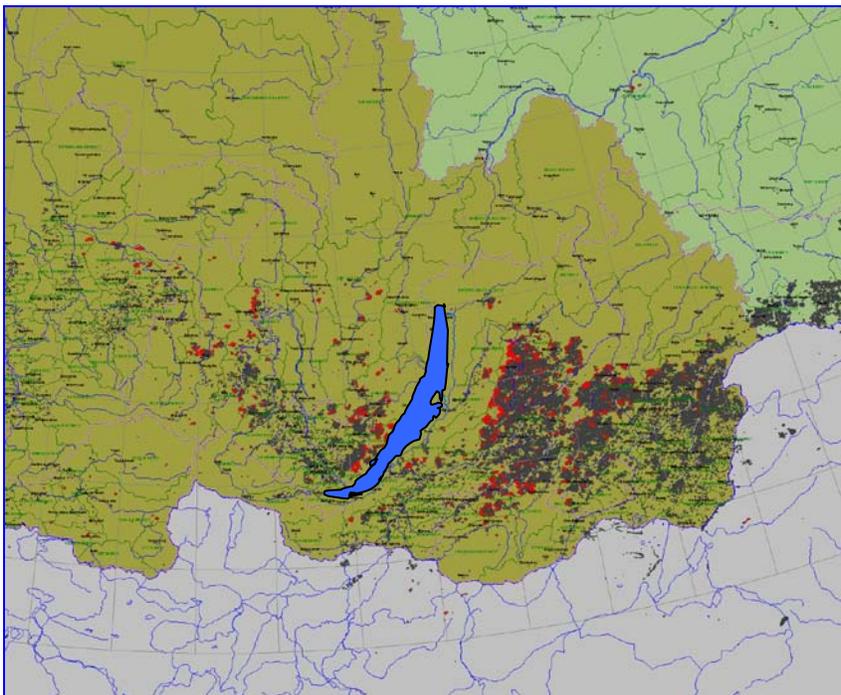


Figure 11. A satellite image of fires burning in Siberia for the period of 6-16 June 2003. Red areas show active hotspots, while black areas show areas previously burned during the current fire season. This fire data period corresponds to the FWI values shown in Figure 10. (Data from Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra and Aqua satellites). Source: Sukachev Institute.

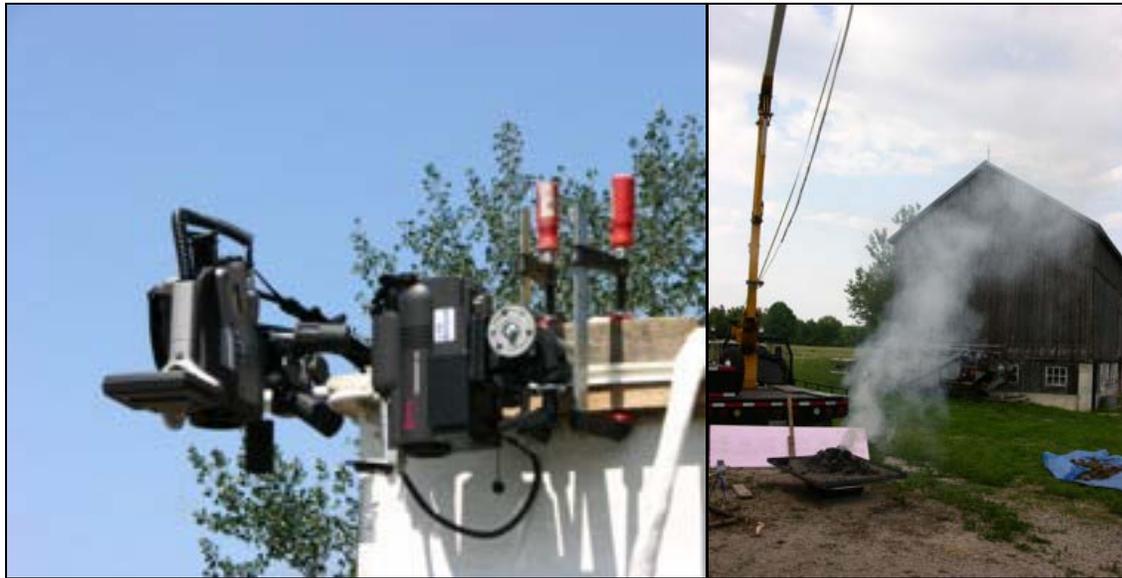


Figure 12. Middle- and long-range infrared cameras (left) were placed over test fires using a boom-bucket truck (right).

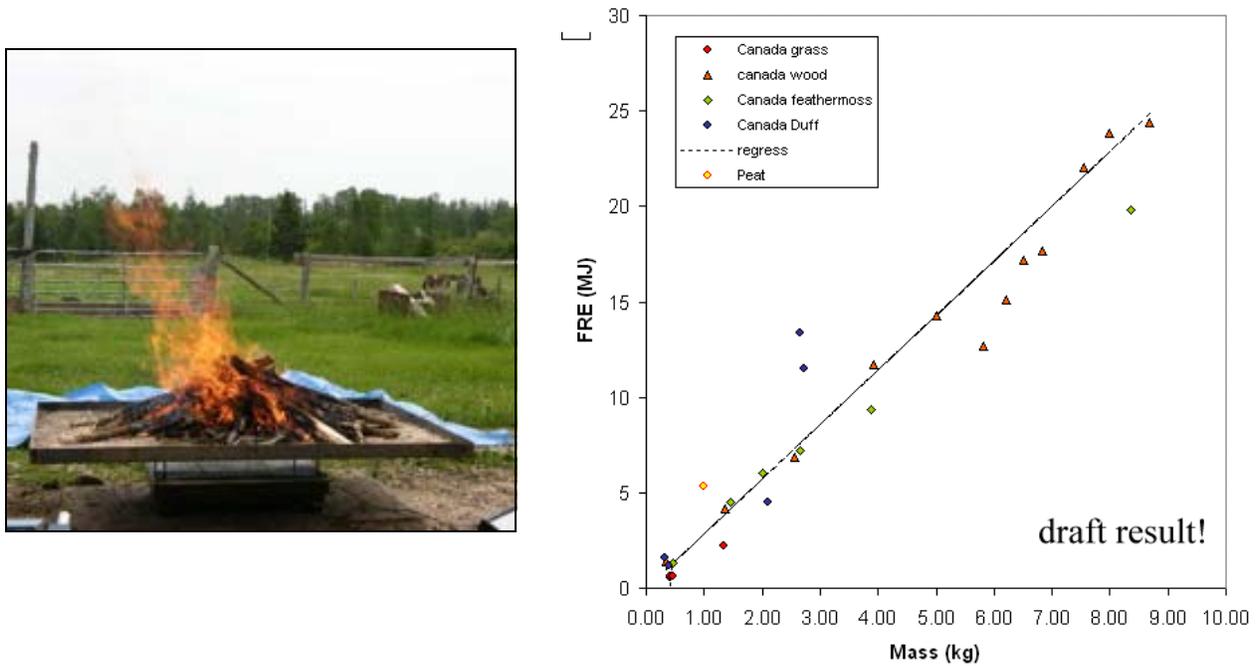


Figure 13. (Left) A test fire burning on a weighing table was used to evaluate the ability of infrared technology to estimate biomass consumption. (Right) Initial results show good correlation between fire radiant energy (FRE) and biomass consumed (Mass) regardless of fuel type.