Modeling and Monitoring Effects of Area Burned and Fire Severity on Carbon Cycling, Emissions, and Forest Health and Sustainability in Central Siberia

Principal Investigator: Susan G. Conard,
Vegetation Management and Protection Research,
USDA Forest Service, P.O. Box 960060
Washington, DC 20250-0001 USA
E-mail: sconard@fs.fed.us; **sgconard@aol.com** (through October, 2001)
Telephone: (202)205-1561; **(202)456-6085** (through October, 2001)
Fax: (202)205-2497 (note- 202-205 numbers will change April, 2001; I do not have new numbers yet)

Co-Principal Investigators:

Name	Institution	Telephone
Anatoly I. Sukhinin	Sukachev Institute of Forest Research Akademgorodok Krasnoyarsk 660036 RUSSIA	Ph: +7-3912-49-4462 Fax: +7-3912-43-3686 e-mail: boss@ksc.krasn.ru
Galina A. Ivanova	Sukachev Institute of Forest Research Akademgorodok Krasnoyarsk 660036 RUSSIA	Ph:+7-3912-49-4462 Fax: +7-3912-43-3686 e-mail: green@escape.santa.krs.ru
Wei Min Hao	Rocky Mountain Research Station USDA Forest Service Missoula, Montana 59807 USA	Phone: (406)329-4838 Fax: 329-4863 e-mail: weiminhao@aol.com
Douglas J. McRae	Natural Resources Canada Canadian Forest Service P.O. Box 490 Sault Ste. Marie, CANADA P6A 5M7	Ph: (705)759-5740, ext. 2180 Fax: (705)759-5700 e-mail: dmcrae@nrcan.gc.ca

Additional major collaborators:
Russian Investigators: Dr. Konstantin Kutsenogy, Institute of Chemistry, Novosibirsk, fire emissions; Dr. Yegor K. Kisilyakhov, Researcher, LFF, SFI, fire physics and chemistry; Dr. Peter A. Tsvetkov, senior researcher, SFI, vegetation development and tree mortality; Dr. Nikolai D. Sorokin, Head, Laboratory of Forest Microbiology, SFI, Microbiology; Dr. Valentina D. Perevoznikova , Research Scientist, Laboratory of Forest Biogeoceonology, SFI, biology and botany; Dr. Olga N. Zubareva, Research Scientist, Laboratory of Woody Plant Biochemistry, SFI, plant physiology, ecology; Dr. Alexander S. Shishikin, senior researcher, SFI and lecturer, Siberian State Technological University, wildlife habitat; Dr. Valeri Ivanov, senior lecturer, Siberian State Technological University, forest meteorology and fire ecology.
North America: Dr. Allen Riebau, USDA Forest Service, Washington, DC (meteorology), Deanne Shulman, Sequioia National Forest, Kernville, CA (fire management and operations); Amber Soja, University of Virginia (remote sensing), Steven Brown, University of Montana (remote sensing).

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ABSTRACT

Boreal forests are extremely important globally, both for their large amount of carbon storage, and as a largely unexploited source of wood fiber. Changes in land use, cover, and disturbance patterns in boreal forests can impact fire regimes and forest health, global carbon budgets, atmospheric chemistry, and wood supply. One of the key disturbance processes in these systems is fire, which affects about 12-15 million ha of closed boreal forest annually, most of it in Eurasia. This exceeds the annual area harvested or disturbed by other natural agents, such as insects.

The Russian boreal forest contains about 25% of the global terrestrial biomass, yet data on the extent and impacts of fire in these forests are scarce and often contradictory. Several recent papers indicate that the impacts on terrestrial carbon storage of fires in boreal forest regions have been vastly underestimated. Furthermore, changes in land management and land use practices, regional climate, and fire suppression capability will affect fire risk and ecosystem damage from fires in ways that are poorly understood. In changing environments, fire can be a key agent to accelerate changes toward new ecosystem conditions. Improved understanding of the landscape extent and severity of fires and of factors affecting fire behavior and intensity, effects of fire on carbon storage, air chemistry, vegetation dynamics and structure, and forest health and productivity is needed before such considerations can be adequately addressed in regional planning. To monitor effects on a landscape scale, and to provide inputs into global and regional models of carbon cycling and atmospheric chemistry requires development of validated remote-sensing-based approaches to measurement of fire areas and fire severities.

The research has three major goals:

- To refine and validate preliminary methods for remote-sensing-based estimates of fire areas and fire severity for forests of central Siberia, by combining ground sampling of burned areas with medium-resolution (15-120 m.) and 1-km resolution satellite data.
- To develop improved data and models on effects of fire severity on fire emissions and on ecosystem damage and recovery for refining estimates of effects of fire regimes on carbon balance, greenhouse gas releases, and forest health and productivity.
- To combine experimentally-derived process data and models with the remote-sensing methods to develop regional estimates of fire areas, fire severity, and the impact of fire on carbon balance, emissions, and forest health.

The information and methods we are developing will provide the basis for recommendations on management of fuels, fire, and fire regimes to enhance carbon storage and sustainable forest management and to minimize negative impacts of fire on global environment, wood production, and ecosystem health.

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, 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; I must also say that much of the success of accomplishing this type of research in Russia rest as much on understanding and working with social customs/habits and administrative structures of the country and the region! Certainly 10-20% of our time is spent dealing with these aspects of the work. In terms of research themes, I would estimate Carbon: 30%; Water: 5%; Nutrients: 10%; GOFC: 40%; other (including fire behavior, ecosystem effects other than carbon, water, or nutrients): 15%.

Overall Research Goals and Approach:

- Combine ground data, aircraft data, and intermediate-resolution satellite data (probably ETM) to improve current AVHRR-based approaches for estimating the spatial extent of fires and to develop and validate methods to estimate spatial patterns of burn severity for forests of the Krasnoyarsk Region. .
- Use ground data from replicated experimental fires to refine estimates of impacts of fire severity and seasonality on fire behavior, emissions, carbon storage, fuel dynamics, and ecosystem damage and recovery.
- Refine regional estimates of fire impacts on fuel dynamics, ecosystem processes, and carbon and trace gases by linking models developed from experimental data to spatial estimates of extent, intensity, and timing of fires.

Goals for Year 1:

- Complete planning for summer 2000 field tests, including pilot tests of experimental burns and overflight of wildfires using infrared technology. Done
- Acquire/build equipment needed for 2000 field season. Done
- Complete site preparation and conduct 2 test burns at Yartsevo study site. Done
- A) Overfly active fires with infrared camera as feasible; B) obtain intermediate resolution satellite data and ground truth data; C) conduct ground sampling on at least one site at each of three severity levels. A-done for one fire; B-not done, but scenes have been selected; C-sampling done at two severity levels.
- Prepare second site (Boguchani) for burning in 2001. Not completed due to administrative problems with leshoz and Federal Forest Service changes.
- Conduct exchange visit for collaboration on remote sensing analysis. Two collaborators (in addition to the main research team) visited Sukhinin lab to discuss methods in detail.
- Hold PI meeting in Russia. PI meeting held in March, 2000; included half-day symposium at Sukachev Institute to present results and several days of meetings with co-investigators and collaborators at Natural Resources Committee and Avialesookhrana.

ACCOMPLISHMENTS TO DATE

This project has been in the planning and developmental stages since early 1996. Site selection and establishment on two experimental areas in the Krasnoyarsk Region and preliminary remote-sensing collaboration were supported by about $34k from the USDA Foreign Agriculture Service plus over $100k in contributed salaries, travel expenses, coordination meetings, site installation costs, and support of preliminary remote-sensing collaboration from the USFS, NASA, and the Canadian Forest Service. Plots were laid out and baseline data on soils, vegetation, and fuels collected prior to initiation of NASA funding. In addition, there were several exchange visits of Russian scientists to the US and Canada and North American scientists to Russia to discuss methods and collaboration and to select and install study areas. Collaboration with the Sukachev Institute on development of remote sensing methods for fire area and severity began in 1991, but has increased greatly over the past two years, in part because of this project. Collaboration and support of the Russian Forest Service (Krasnoyarsk Region Forestry Committee, Avialesookhrana, and local leshozes and airbases) developed over several years is integral to the success of this program

Year 1 accomplishments:

As a result of our planning activities we were able to complete preparation of study plots at Yartsevo for burning; fire lines were installed by Yartsevo regional airbase; baseline data collection was done primarily by our Russian collaborators in consultation with Douglas McRae. One of our biggest accomplishments in this area has been that:

- **All investigators have agreed to tie their data collection to a common grid system, enabling excellent spatial correlation across data bases.**

While there were some administrative problems surrounding conduct of the experimental burns; these were temporarily resolved (again possible due to our long-term relationships in the Region).

- **Two 4-ha burns were conducted at Yartsevo site July-August (1 low severity; 1 high severity surface fire); prefire, during fire, and immediate postfire sampling conducted included: fuels, vegetation and stand structure, soil characteristics, small animal populations, insects, fire damage estimates, fire behavior (on ground and using helicopter-based infrared camera); fire and soil temperature; fire weather (see attached figures 1-3).**

We were also able to being our program of gathering aircraft data from wildfires for correlation both with experimental ground data and with AVHRR and higher-resolution satellite imagery.

- **We obtained excellent images from overflight of a low-intensity wildfire 130 km south of Yartsevo with infrared camera and still photography (see attached figure 4).**

Over the winter considerable progress was made on data exchange and data analysis. While some restrictions placed on release of infrared data by the Russian government; these data also were cleared for our use by early March. Highlights of accomplishments include:

- **Most summer 2000 field data were analyzed and exchanged between North American and Russian partners. Data repositories were established at Krasnoyarsk and the Canadian Forest Service.**
- **Analysis and methods development continued for estimating burned area from AVHRR (see attached figures 5, 6).**
- **A poster was prepared to illustrate project goals and accomplishments to government officials, potential collaborators and funding sources, and project participants (figure 7).**

CONCLUSIONS

Overall, we have felt this year was tremendously successful, more so than might be expected given the changes and uncertainties in the Federal Forest Service over the past year. Our mutual collaboration with Russian investigators has been excellent, including developing a culture of data-sharing, which does not come naturally to Russian (or even US!) scientists. Our main problems in the first year centered on obtaining official permission for use of the land, for burning, and for aircraft remote-sensing work. One result was that local authorities became concerned about our collection and use of spatial data, and our aircraft data were only recently released to North American collaborators. While we still managed to get done essentially what we had planned, and we now have most of the permissions required for the coming summer, this will continue to be an issue that takes considerable time and discussion with the Regional Natural Resources Committee, the leshozes, the regional Geodesic Committee and "FSB", and Forest Service personnel in Moscow.

A general problem that NASA may need/want to get involved in at higher levels is that current regulations prohibiting collection and retention of essentially all kinds of spatial data by foreigners are being more and more strictly enforced in Russia now. I have great concern that some more naïve and less well-supported (by Russian colleagues) groups of foreign researchers could end up in serious legal trouble or even in jail.

Preparation of Boguchani site for burning also did not occur. This was due to complications getting final official permission from the leshoz for use of the land. We are still working on it. If permission is not obtained by early summer, we will identify another site with assistance of the regional forest service. Another potential major problem is bringing equipment and samples into and out of Russia. We had some problems with the infrared video camera last year, although they were resolved fairly speedily, but restrictions are getting tighter rather than looser. We know other groups that have been less successful, which we see as a clear warning to develop more careful procedures. We are now trying to work out better procedures for equipment transfer so that we avoid problems with customs regulations, etc.

The bottom line, however, is that despite some difficulties, we now have, without a doubt, one of the most comprehensive data sets on a set of fires ever collected in the boreal zone, and perhaps anywhere in the world. As we build this data set through more experimental fires and oveflights of wildfires, this will only continue to improve; we anticipate that we will be successful in meeting all project objectives.

Publication completed:

Conard, Susan G., Anatoly I. Sukhinin, Donald R. Cahoon, Eduard P. Davidenko, Brian J. Stocks, and Galina A. Ivanova. *Determining effects of area burned and fire severity on carbon cycling and emissions in Siberia.* Climatic Change (accepted for publication).

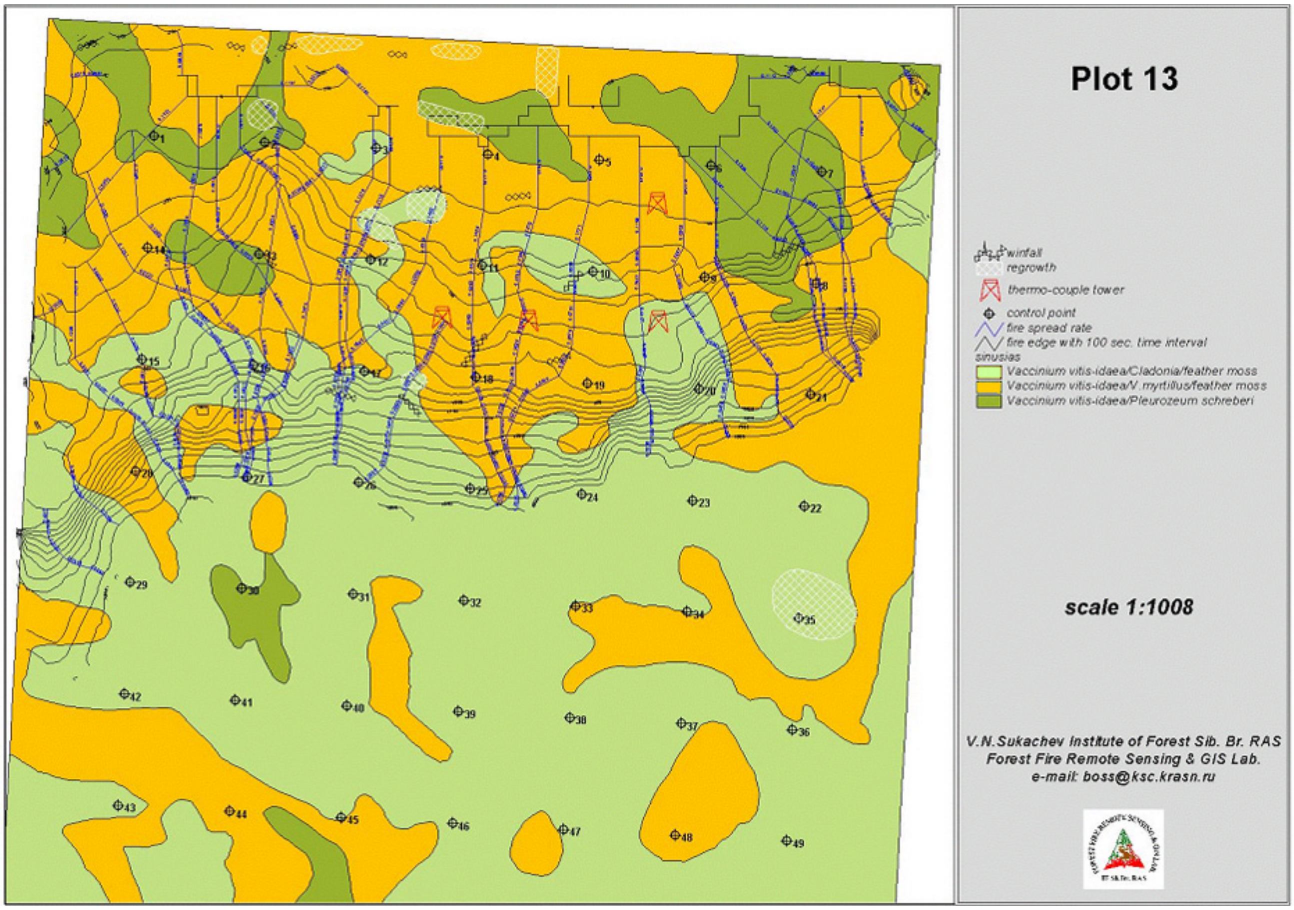

Figure 1. Map of experimental plot 13 showing understory vegetation types, the grid system used to coordinate all ground measurements (points 1-49), and location of the thermocouple towers for measuring fire and soil temperatures. The data on fire fronts and rate of spread of the fire (from aerial infrared camera) is overlain on the upper half of the plot.

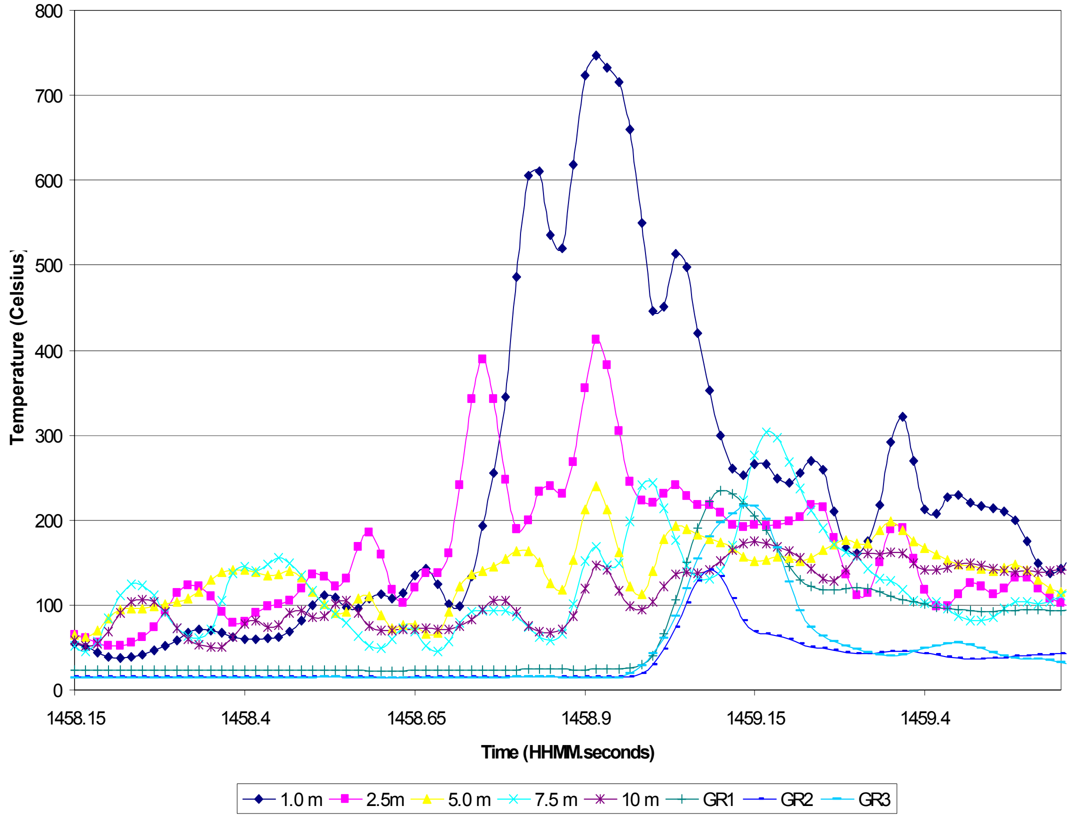

Figure 2. Example of data on time course of fire temperature at different heights above ground (1 to 10 m); the soil surface (GR1) and two depths in the soil (GR2, GR3).

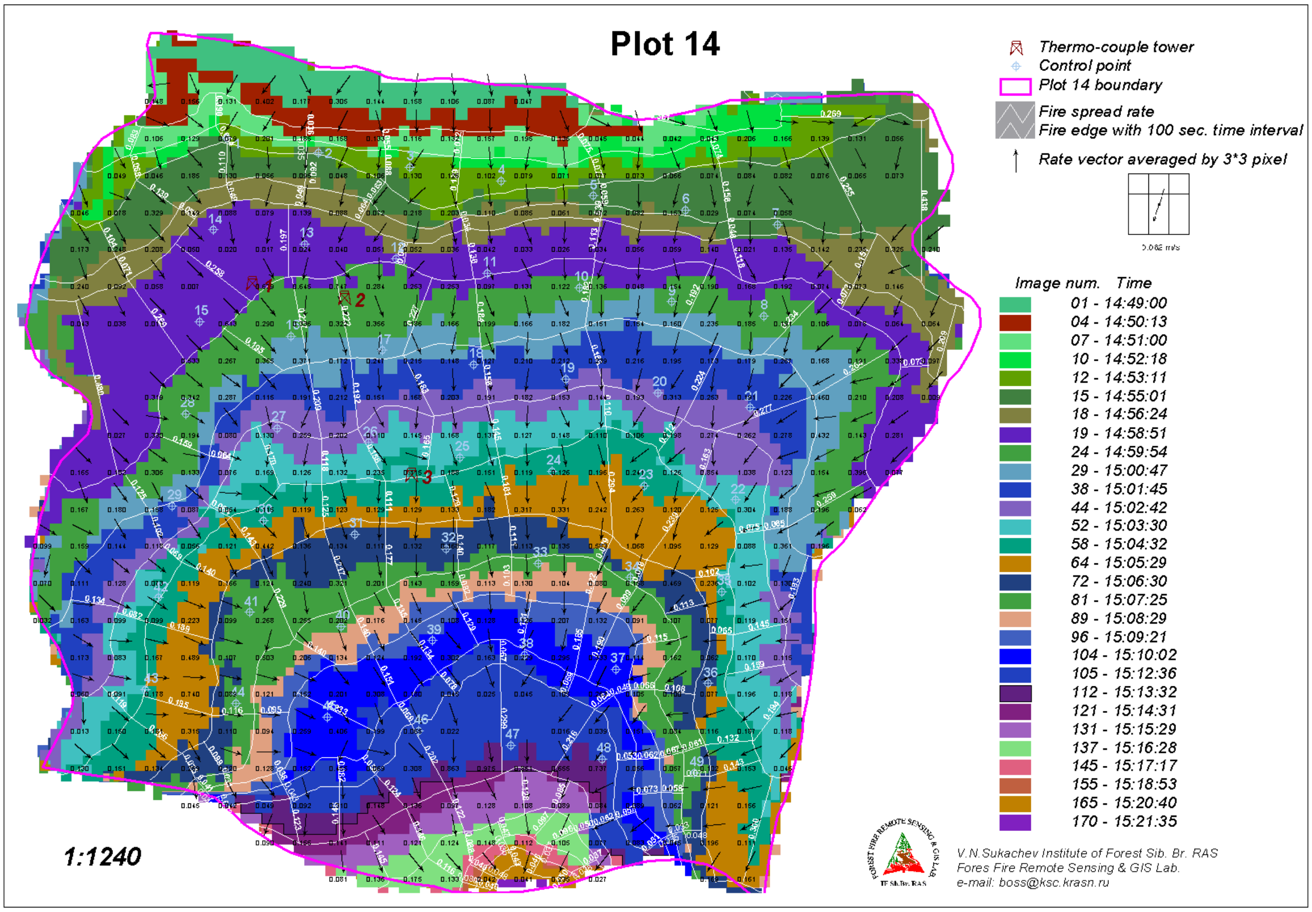

Figure 3. Preliminary map of fire spread for Plot 14, based on infrared data from helicopter. Arrows indicate direction of spread, and numbers perpendicular to fire front indicate spread rates.

Фрагменты ИК съемки естественного пожара, СШ 59°55’ ВД 88°08’
(азимут 245°, удаление 130 км от п. Ярцево)

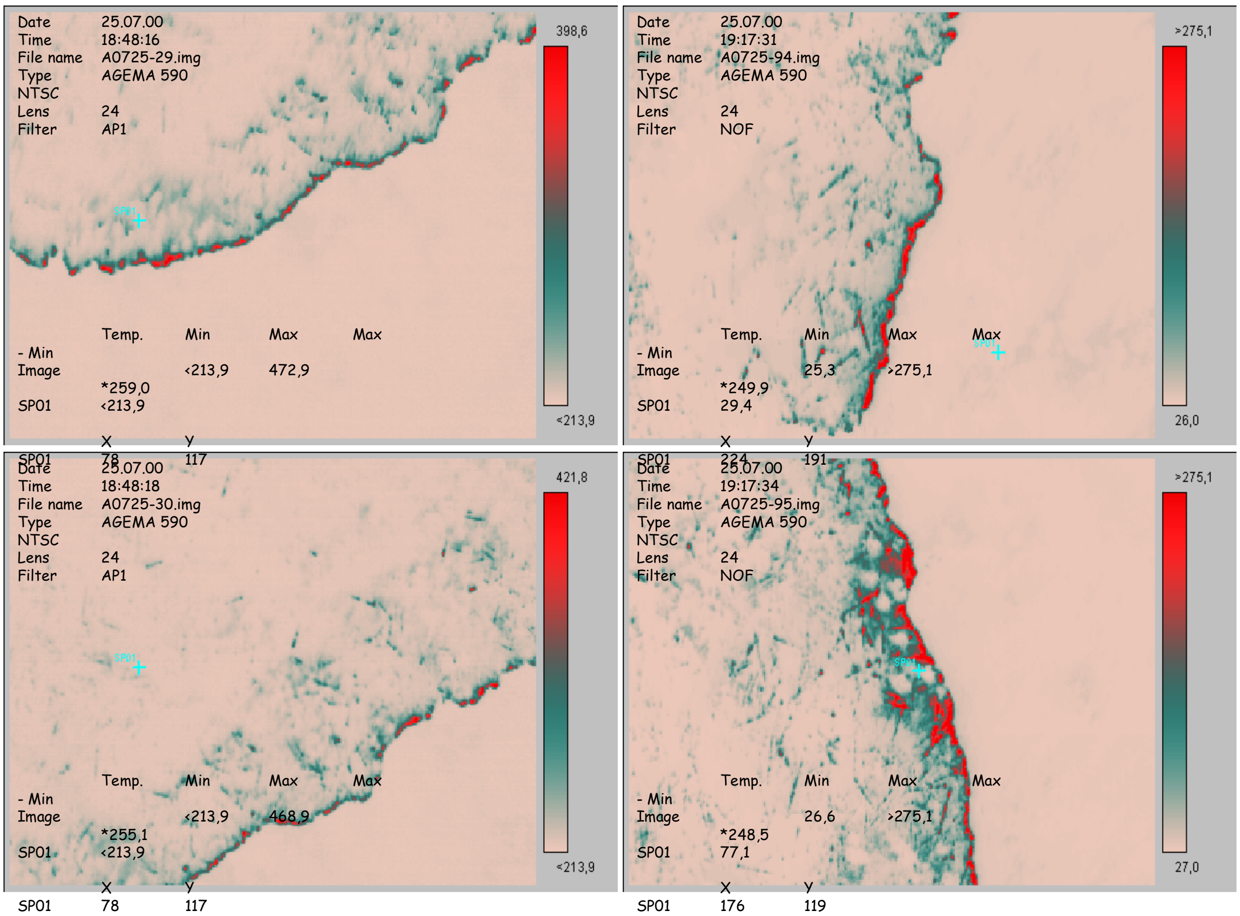

Figure 4. Infrared images of a wildfire from the region near our Yartsevo study site. This was a low-intensity surface fire. Such images will allow us to better interpret the signatures from actively-burning fires on AVHRR images (and in the future on MODIS images).

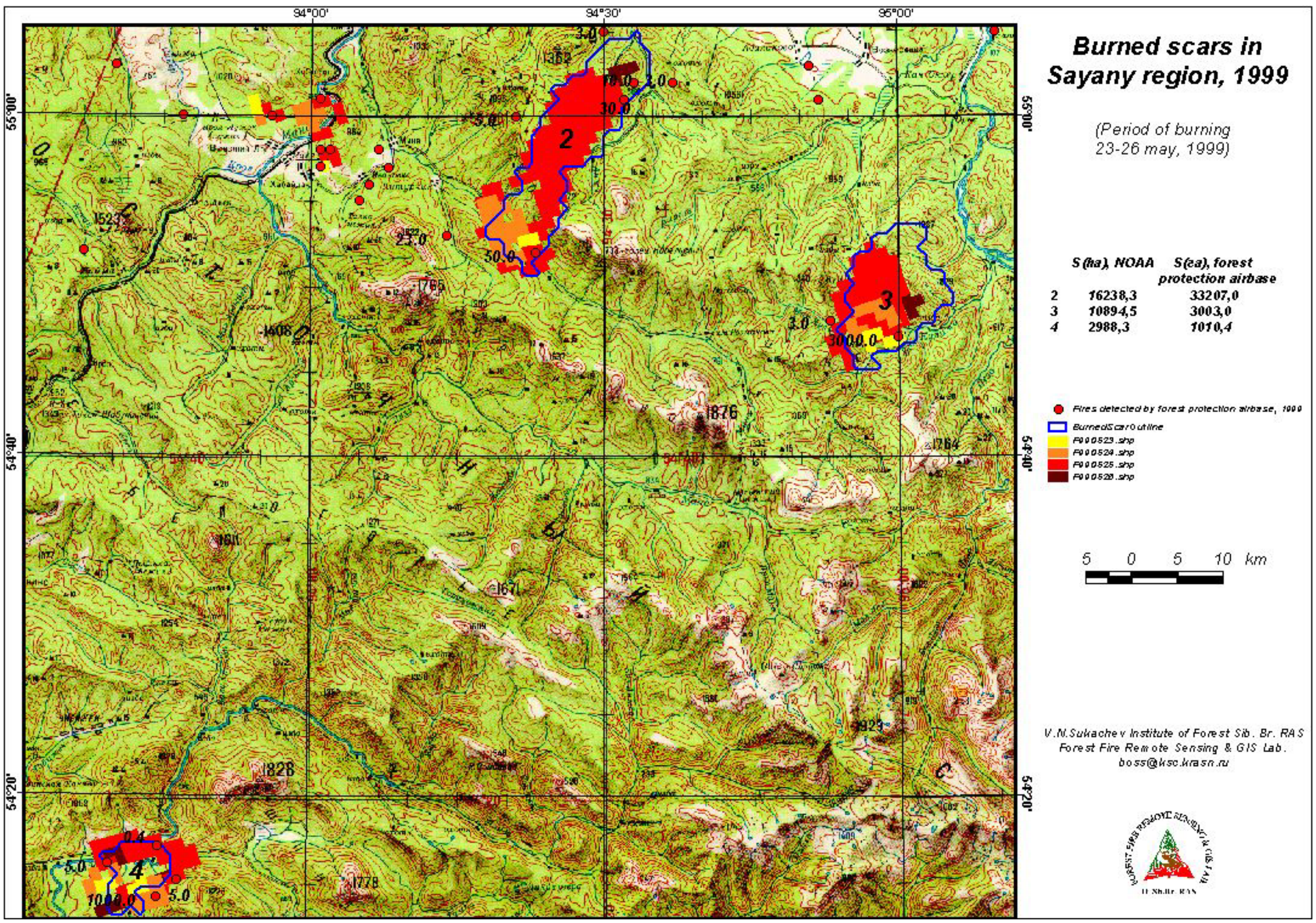

Figure 5. This composite from the Sayan Region illustrates the capacity to overlay active fire pixels and fire scars from AVHRR images onto terrain maps.

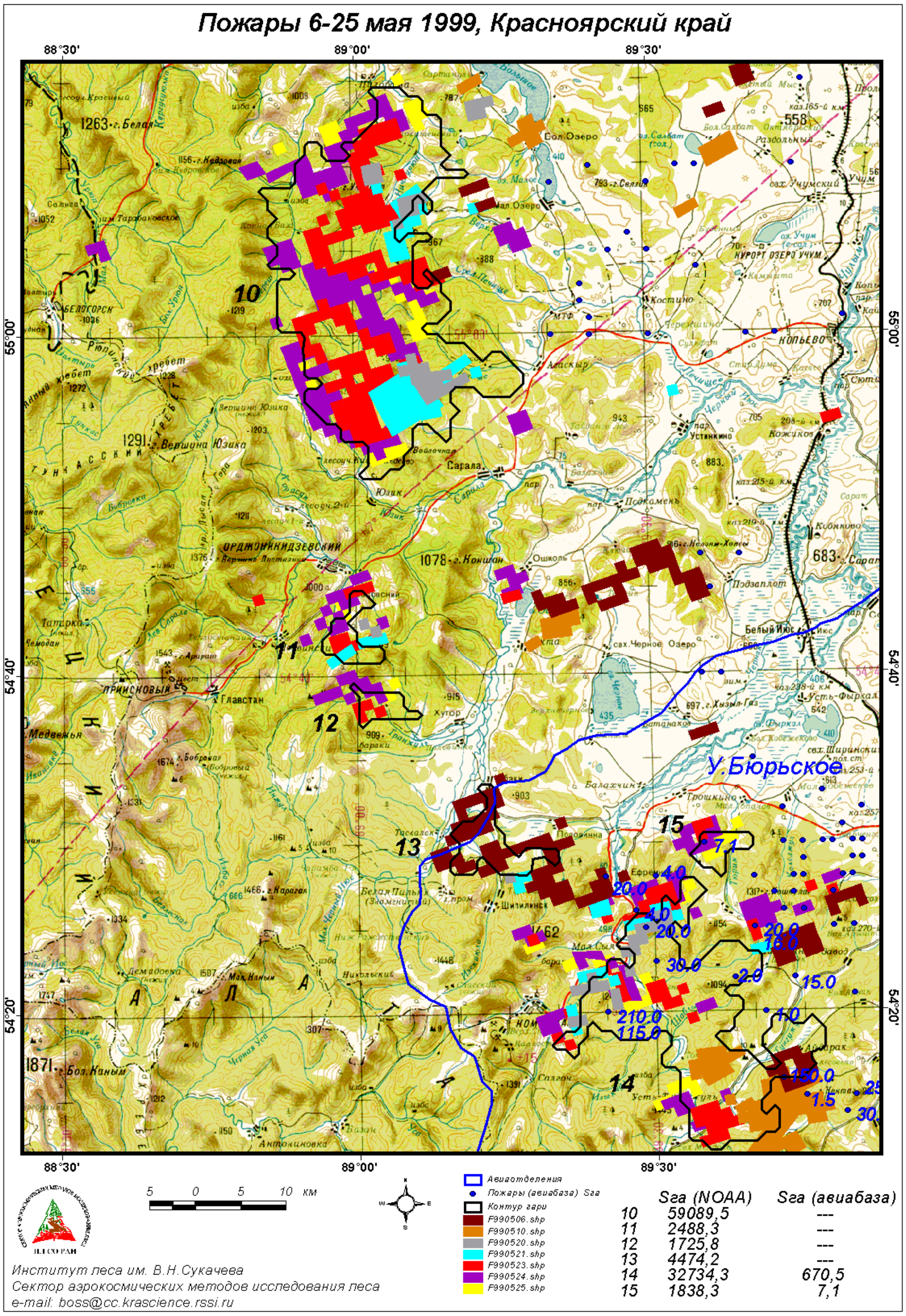

Figure 6. An illustration from the Krasnoyarsk region of the relationship between active fire pixels mapped on several successive days and the burned areas mapped by the regional airbase.

Figure 7. Poster produced (in both English and Russian) to describe the project.