NASA's Land Cover Land Use Change Program

The Russian FIRE BEAR Project

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

U.S. Civilian Research & Development Foundation

Introduction:

Boreal forests are important globally as major carbon reservoirs, as relatively undisturbed natural ecosystems, and as sources of wood fiber and other forest products. Changes in land use, cover, and disturbance patterns in boreal forests can impact fire regimes and forest health, global carbon budgets, atmospheric chemistry, wood supply, and sustainability of local subsistence economies. Wildfire is a key disturbance process in these systems, and fire 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 any other natural agents, such as insects.

The Russian boreal forest contains about twenty-five percent of the global terrestrial biomass, yet data on the extent and impacts of fire in these forests are scarce and often contradictory. Several recent studies 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, 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 Russian FIRE BEAR (Fire Effects in the Boreal Eurasia Region) Project is a research study in central Siberia developed to provide answers to these basic questions on the management of fuels, fire, and fire regimes to enhance carbon storage, and forest sustainability in ways that minimize negative impacts of fire on global environment, wood production, and ecosystem health.

Research Objectives

(1) To use experimental fires of varied intensity to measure fire behavior, and effects of fire severity on combustion, emissions, and ecosystem impacts for estimating effects of fire regimes on carbon balance, greenhouse gas releases, and forest health and productivity.

(2) To refine and test 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.

(3) To combine process data and models developed through experimental fires with remote-sensing to produce validated regional estimates of fire areas, fire severity, and the impact of fire on carbon balance, emissions, and forest health.

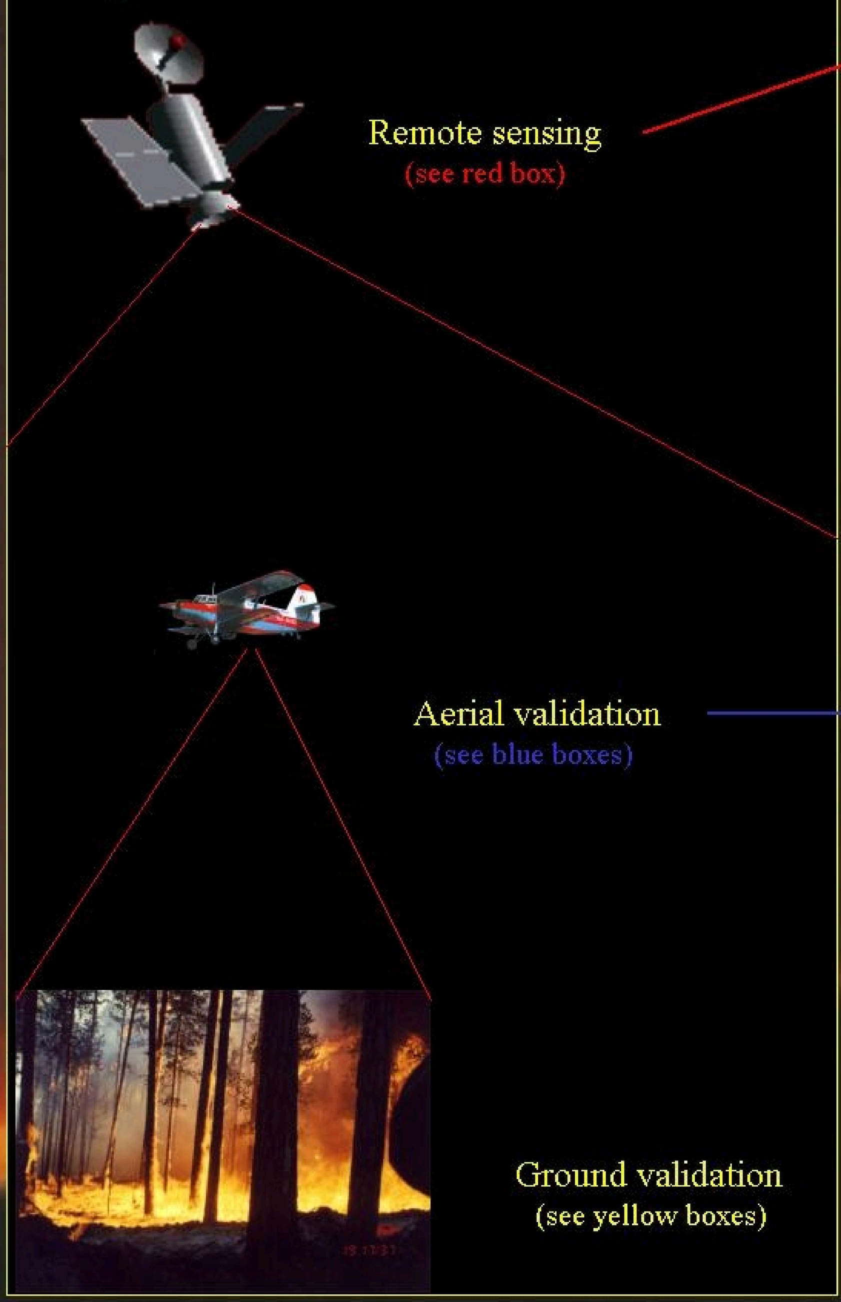
(4) To provide information and tools useful for fire management decision making and for evaluating possible future use of prescribed fire.

Study area

Research burn sites have been located at two sites sites in the Krasnoyarsk Region of central Siberia near the villages of Yartsevo and Govorkova. Both sites represent a scotch pine/lichen/feather moss forest type located on a dry site. Replicated experimental plots of about 4 ha were installed on both sites, and baseline data was collected on vegetation, fuels, soils, and other ecosystem characteristics. Experimental plots are burned under a range in burning and fire behavior conditions to observe effects. Onsite environmental data, construction of protective fire lines, and collaboration between fire crews of the Federal Forest Service of Russia and prescribed fire experts from North America, help ensure that the fires are safely maintained inside the plots. The experimental plots are burned using line ignition along the windward side to quickly create equilibrium fire behavior that mimics wildfires under similar burning conditions.

Research approach

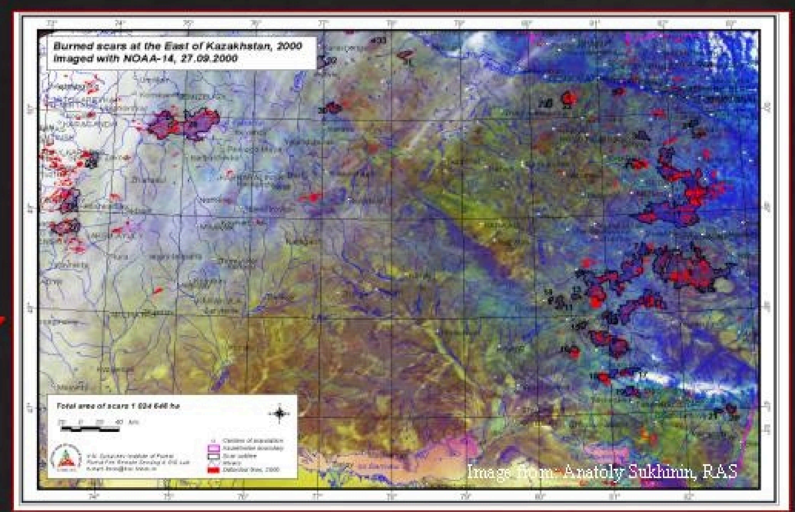
A 3-prong research approach has been developed to combine multi-scale satellite, aircraft, and ground data, to test and improve on current satellite-based approaches for estimating the spatial extent of fires and to develop and validate methods to estimate spatial patterns of burn severity.



Project highlights

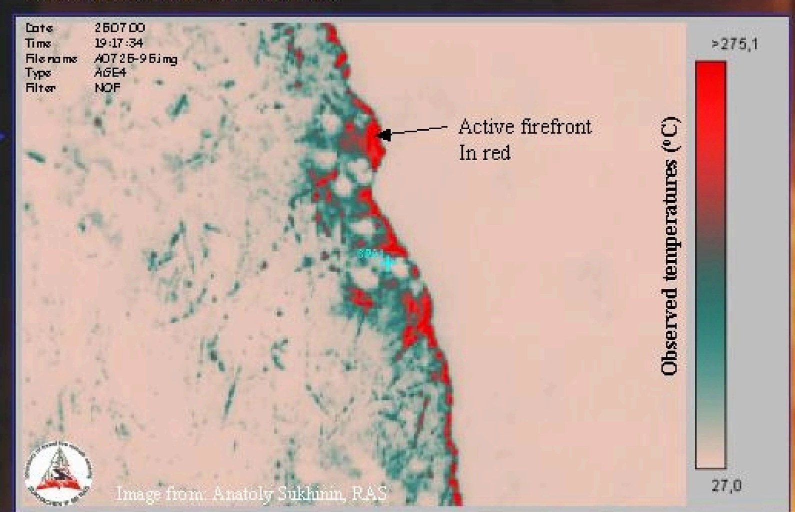
- Quantitative ground-validation data for fire behavior in Russia
- Field measurements of carbon consumption and emission characteristics from fires of different severities
- Development of fire behavior and carbon release models for fires of varying severity
- Aerial observations of wildfires and experimental fires to assess fire severity and monitor fire intensity
- Refinement of remote-sensing procedures for estimating areas burned annually in Russia.
- Field validation of fire severity for wildfires observed from aircraft and satellite.
- ETM validation of burned area estimates from AVHRR
- First spectra data obtained in field for burned areas and unburned vegetation to assist in remote-sensing interpretations
- Fire-effect studies coupled with actual quantifiable fire behavior data to understand ecological responses and recovery better

Remote sensing

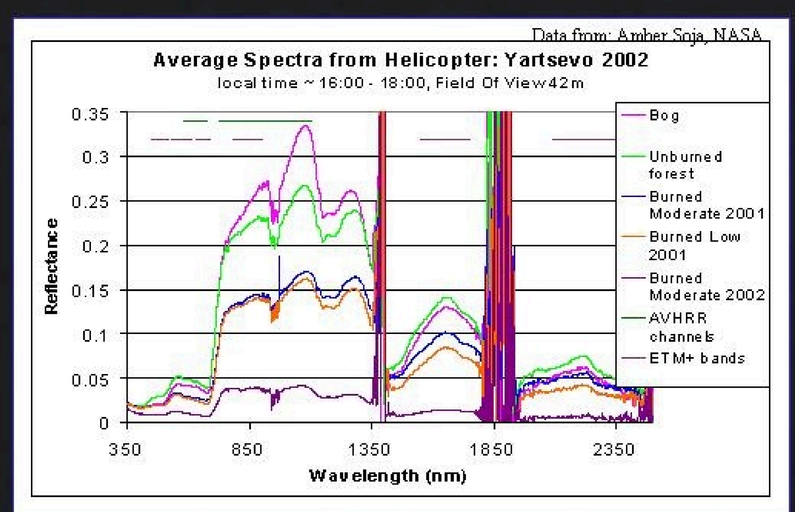


On a landscape basis to understand emission of green-house gases, remote-sensing analysis will need to not only detect fire scars but will also need to be able to assess fire severity. The FIRE BEAR Project is developing procedures to ensure that these projections can be realized. Important ground and aerial validation is being undertaken to achieve this.

Aerial validation



Infrared data taken on wildfires in the Yartsevo Region is used to quantify the actual fire behavior coupled with on-ground sampling. Aerial observation of wildfires provides a necessary step in relating on-ground validation with remote-sensing observations.



Spectra data was collected aerially on different burn sites in 2002, which is the first attempt to do so on any actual burns. The graph shows the unique signature between burn years. This showed that the spectra was not masked by the "green" overstory trees. This information will be important in interpreting fire scenes on remote-sensing images.

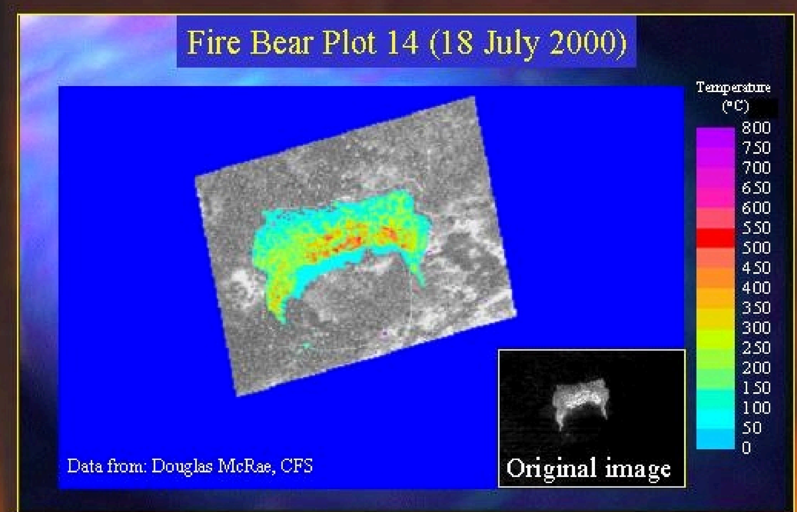
Ground validation

The project has successfully conducted 13 experimental fires at the Yartsevo site (2000-2002) on 4-ha replicated plots. Two additional fires were completed at Govorkovo in 2002. Typically, most burns are surface fires because of the lack of ladder fuels in the understory that would initiate crown fire development. This reduces the amount of tree mortality normally expected on wildfires.

Of the 15 experimental fires conducted to date, this picture shows the only fire that crowned when a dense cluster of young regeneration was encountered. However, the fire dropped back down to the surface quickly when mature trees were once again encountered. Models were developed to predict the fire behavior expected under different burning conditions.

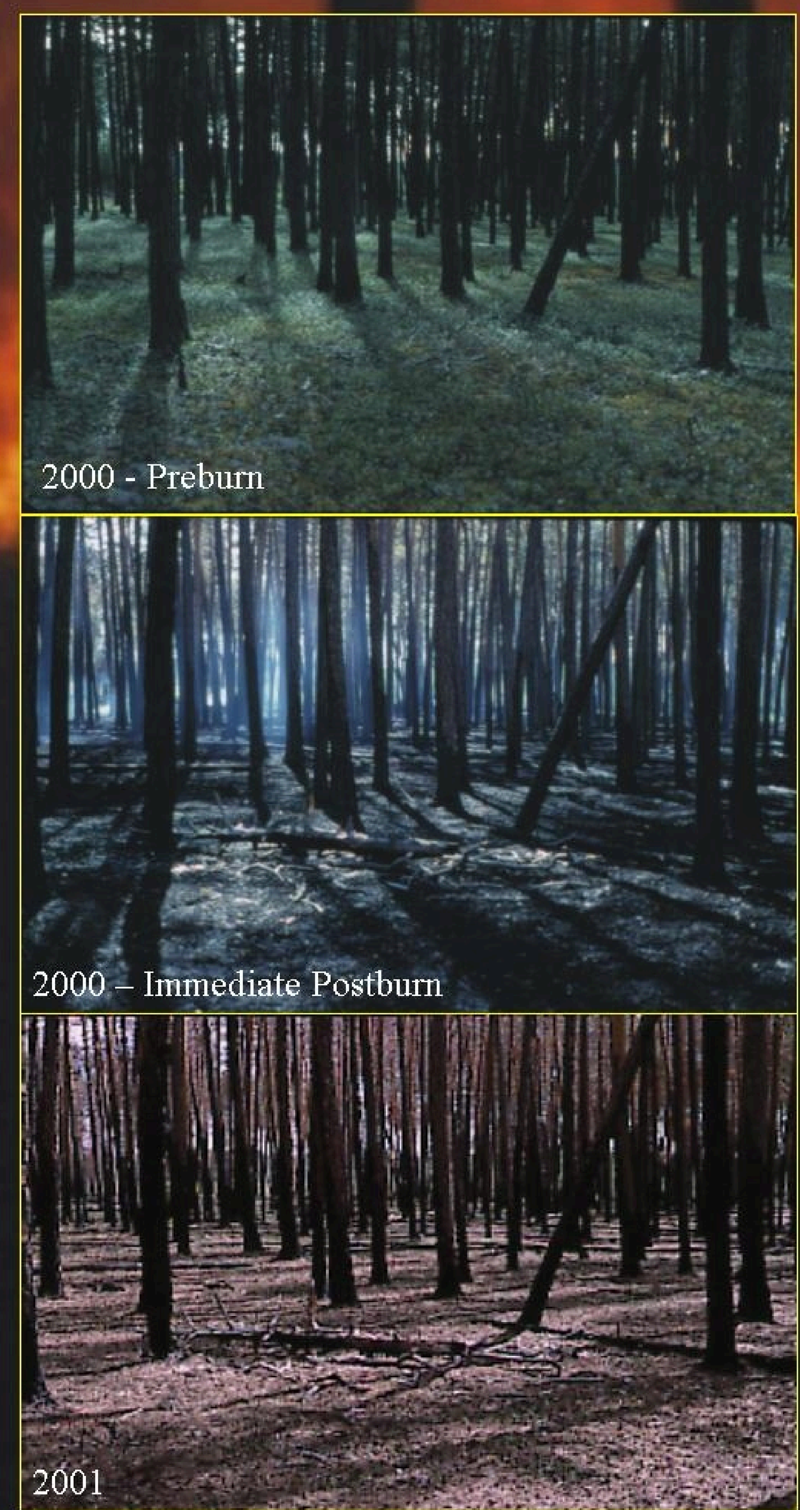
Interesting fire behavior phenomena such as this large fire whirlwind can develop on the higher intensity burns. During these surface fires, the ground fuel (forest floor) is the most significant contributor to carbon release. Expected carbon release can range from 4.8 to 15.4 t/ha depending on fuel consumption. Additional sources of carbon come from litter, and the down woody fuels.

Surface fires can range from benign fires that cause very little visible canopy damage (Plot 13) to high-intensity fires that can cause extensive tree mortality (Plot 14). The benign fires may be more difficult to detect from remote-sensing images since the upper forest stand structure remains green. This hides the blackened char surface that exists at ground level.



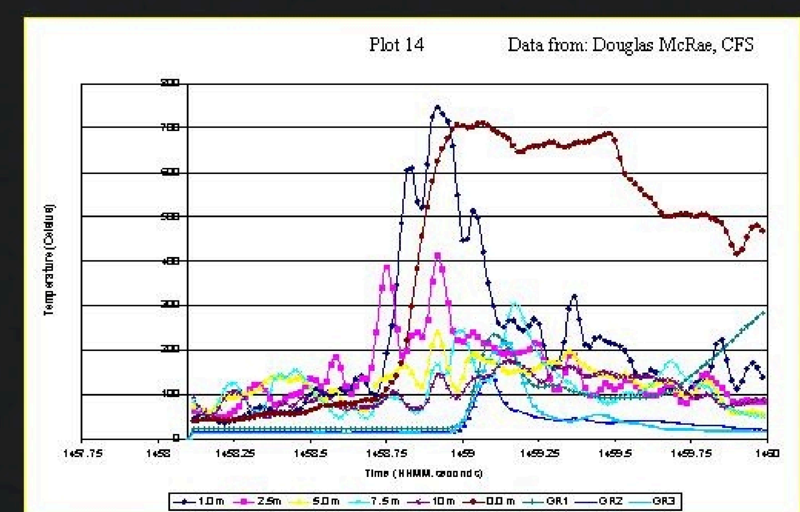
A series of infrared images taken aerially during the fires (see lower inset) are analyzed to help quantify various fire behavior parameters (e.g., rates of spread, fire temperatures, reaction intensity, etc.) that can characterize fire severity.

Continuous sampling prior to and after all experimental fires provides data to understand fuel loads, carbon storage, and ecological fire effects (e.g., vegetation, soil, disease, insects, wildlife, etc.) related to the different fireline intensities attained.

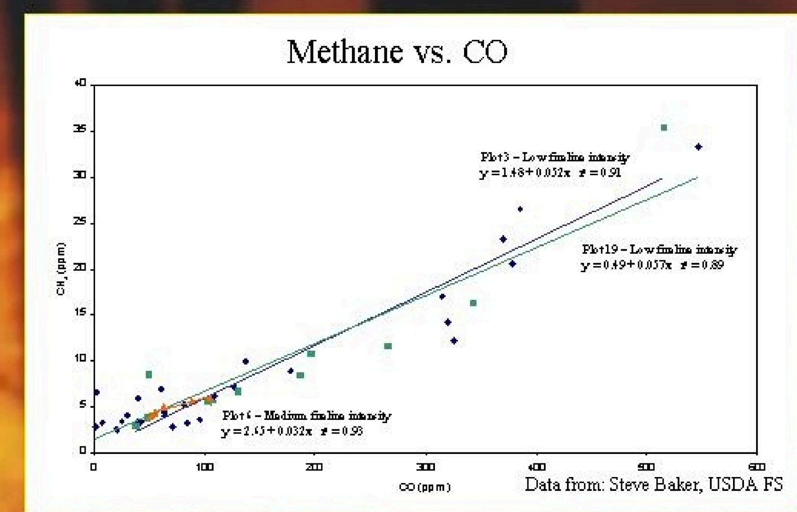


Fuel and carbon inventories are taken annually to understand the effects of forest fire on carbon dynamics.

Emission samples were taken at various combustion phases (flaming and smoldering) at ground level and aerially (inset) above the tree canopy. A number of trace gases were measured (hydrogen, carbon dioxide, carbon monoxide, methane, ethylene, ethane, propylene, propane, and sixteen $C_4 - C_6$ hydrocarbons).



An array of thermocouple towers were used on each plot to record temperatures at various heights above the ground starting at the surface to 10 m above the ground. In addition, 3 measurements were taken at different depths in the soil.



Emission factors for CO_2, CO, CH_4, ethylene, ethane, propylene, and propane were produced for different fire intensities. Emitted hydrogen concentrations were highly linearly correlated with CO concentrations for the 3 fires sampled by helicopter in 2001. No significant differences were found in the ratios of different trace gases to CO for different fire intensities or understory vegetation.

Collaborators include the Canadian Forest Service, USDA Forest Service (Research and Development, Washington DC; Fire Sciences Laboratory, Missoula, MT.; Sequoia National Forest, CA.) National Aeronautics and Space Administration (NASA), Russian Academy of Sciences, Siberian Branch (V.N. Sukachev Institute of Forest Research, Krasnoyarsk; Institute of Chemical Kinetics and Combustion, Novosibirsk), Moscow State University, Federal Forest Service of Russia - Forestry Committee of Krasnoyarsk Region, Federal Forest Service of Russia - Forest Protection Airbase, Krasnoyarsk Region

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