FIRE BEAR Project: Effects of Fires on Carbon Cycling in Siberian Forests

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Introduction

The Russian boreal forest contains about thirty percent of the global terrestrial carbon storage. A key disturbance process in these systems is wildfire, which affects about 10-20 million ha annually, most of it in Eurasia. Fire behavior and impacts are highly variable across this landscape. Information on fire severity and its effects on factors such as emissions, carbon storage, and ecosystem recovery are scarce. Changes in land management and land-use practices, regional climate, and fire suppression capability will have complex effects on landscape fire regimes. 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 to adequately characterize impacts of wildfire. To estimate effects on a landscape scale, and to provide inputs into models of carbon cycling and atmospheric chemistry, requires combining ground-based data and models with validated remote-sensing-based approaches for estimating burned areas, fire severity, and emissions. The FIRE BEAR (Fire Effects in the Boreal Eurasia Region) Project was created to provide data and models required to answer these needs. Research is being carried out in Scots pine (*Pinus sylvestris*) and larch (*Larix* sp.) forest types, which together make up 58% of the area of forest in the Asian part of Russia

Research Goals

The major objective of this research is 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 is building on our past research efforts in Scots pine forests (2000-2004), while initiating similar research in larch forests by:

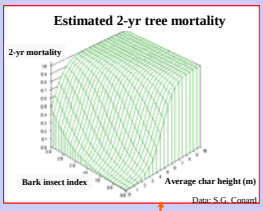
- Quantifying and modeling effects of different severity fires on Scots pine sites to estimate effects of fire severity on carbon cycle, direct fire emissions, and forest dynamics.
- Developing models relating fire behavior, fire weather, and fuel condition at the time of burning to carbon emissions, energy release, and other ecosystem impacts.
- Building on our past work on Scots pine forests to study effects of fire on carbon cycle in larch forest types. Quantitatively characterizing 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.
- Evaluating the potential for estimating emissions directly from satellite infrared channels through relationships between the fire's energy release and its emissions.

Research Approach

A 3-prong research approach has been developed that combines multi-scale satellite, aircraft, and experimental ground data 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 Siberian forests.

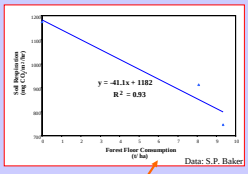
TREE MORTALITY

Current Data and Products: We have developed mortality models for Scotch pine that relate burn damage and postfire insect damage to tree mortality.
Application: Tree mortality in fires in central Siberia varies widely as a function of burn severity and fire behavior. Models of tree mortality will help us to predict fire severity from satellite images and to estimate effects on above-ground carbon storage.
Outside Data Needs: None.



TREE BLOWDOWN AND DECAY

Current Data and Products: We are collecting data on when trees killed by high-intensity fires begin to fall over.
Application: This will account for long-term postfire changes in carbon storage of trees killed by a high-intensity fire (i.e., from stable storage in standing dead snags to carbon sources as trees blow over and begin to decay).
Data Needs: Information on decay rates for down woody material in Siberia.

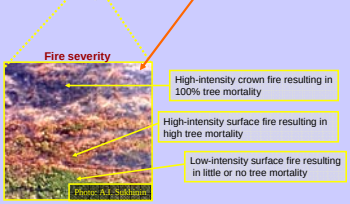


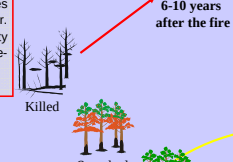
SOIL RESPIRATION

Current Data and Products: Soil respiration on Scotch pine sites decreases after fire. The decrease is greatest, and lasts longest, on the most severely burned sites. This reduction in soil respiration may balance out much of the direct carbon loss from surface fires in Scots pine.
Application: Prediction of postfire soil respiration and the effect in countering the original impact of carbon emitted by the fire.
Data Needs: Seasonal soil temperature and moisture data.

REMOTE SENSING VALIDATION

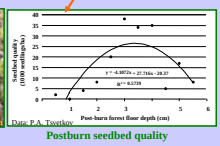
Current Data and Products: Aerial and on-ground validation data have been collected on wildfire severity and vegetation characteristics present on postfire sites monitored by satellites.
Application: These data will help to characterize wildfire severity and impacts using satellite data and relate it to effects on carbon cycling in Siberian forests.
Data Needs: Cloud-free satellite data for Siberia, particularly for years prior to 1996 to help build historical burn severity data.





CARBON (BIOMASS) RECOVERY

Current Data and Products: We have collected data on changes in ground vegetation, tree seedlings, surface fuels, soil microorganisms, and soil carbon following fires of different severity.
Application: To determine biomass and mortmass changes and estimate how burn severity affects carbon storage changes following fire.
Data Needs: Growth and yield data for various forest types.



CARBON EMISSIONS

Current Data and Products: We have obtained ground-based and aerial smoke data from 14 experimental fires. Emission factor models allow us to break down emission components into CO, CO_2, methane, etc.
Application: Better understanding of fire emission components and their potential impacts on atmospheric chemistry and greenhouse forcing.
Outside Data Needs: None.

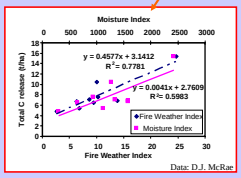
CARBON SOURCE

CARBON SINK

50 year fire return interval

FIRE BEHAVIOR AND CARBON CONSUMPTION

Current Data and Products: We have developed models to predict fire behavior and carbon consumption based on fuel characteristics.
Application: These models will allow us to combine weather and fuels data with remote-sensing data to estimate carbon emissions from combustion of forest fuels.
Data Needs: None.



Carbon release estimates

PREFIRE CARBON STORAGE

Current Data and Products: A complete inventory has been made on the prefire carbon storage at each of our sites.
Application: A better understanding of the carbon storage capability of mature Scots pine stands in Siberia and the effect of fire on it.
Data Needs: None.

FIRE RETURN INTERVAL

Current Data and Products: Based on new methods of data analysis and interpretation, the mean landscape-scale fire return interval for our sites has been approximately 50 years for several centuries, compared to a shorter 25-35 year interval reported by other studies. Our data provide an estimate of frequency of both surface fires and stand-replacement fires, which occur about every 140-150 years.
Application: Better estimates of the fire regime (frequency and severity) in Siberia and its effect on carbon storage.
Data Needs: Data from previous studies for reanalysis to confirm the exact fire return interval for Siberia.

Future Experimentation and Fieldwork

Active since 1999, the FIRE BEAR Project has the following on-going research activities:

- Continue postfire data collection on our Scots (*Pinus sylvestris*) pine sites in central Siberia for refining estimates of effects of fire severity on carbon cycle, direct fire emissions, and forest recovery and productivity. This year we will have data for up to five postfire years after burning. *Postburn sampling planned for July and August 2006.*
- Conduct experimental fires and sampling on 1-ha larch sites in the Nevinsky Leshoz to obtain data on fire severity, fire behavior, fire emissions, biogenic emissions, carbon storage, fuel dynamics, and ecosystem impacts. *Burn experiment planned for late July 2006.*
- Locate and complete prefire sampling and site preparation on new larch burn sites for anticipated burning in 2007. *Site selection to be completed by August 2006.*
- Continued monitoring of wildfires to collect validation data on spatial patterns of burn severity in support of developing methods for classifying the spatial distribution of burn severity from satellite data. Fly active fires using infrared and visible instruments. Conduct follow-up ground truth sampling and analysis of intermediate resolution satellite data. *Aerial monitoring will be conducted in July-August 2006 in central Siberia.*
- FIRE BEAR collaborators are currently producing research papers on fires in Scots pine forests for publication as a special issue of the International Journal of Wildland Fire. *Expected release of this issue is early 2007.*

NEESPI Leadership: Addressing Field Campaign Needs

Although we have ultimately been able to meet most project timelines, we have experienced multiple problems in carrying out experimental projects with Russia. These can be grouped as:

- Recent difficulties in obtaining suitable experimental sites as forest management is being transformed to a long-term tenure (rental) system in forest use.
- The need for obtaining multiple permits (e.g., land use, burning, aircraft, infrared monitoring, etc.) for carrying out the experiments along with later claims of damage to the site.
- Inability of foreigners to operate any equipment in Russian aircraft.
- The need for all aerial data obtained in Russia to be screened by the Technical Committee under the guidance of the Federal Security Bureau. It can take over a year for data to be released for analysis.
- A new regulation requires all equipment to be checked by a Technical Committee--a process that can take over a month. This makes it difficult to bring equipment into Russia as part of personal luggage. We are concerned that expensive and calibrated equipment could be destroyed if tested improperly.
- Complicated customs procedures, fees, and delays for equipment sent to Russia.

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