Integrating Historic Patterns of Wildfire, Emissions, and Climate for Siberia as a Basis for Estimating the Impacts of Fire on Carbon Cycling, Quantifying Past Fire/Climate Interactions, and Projecting Future Fire/Climate Change Impacts

The Russian FIRE BEAR Project
Fire in the Boreal Eurasian Region

Proposal Summary

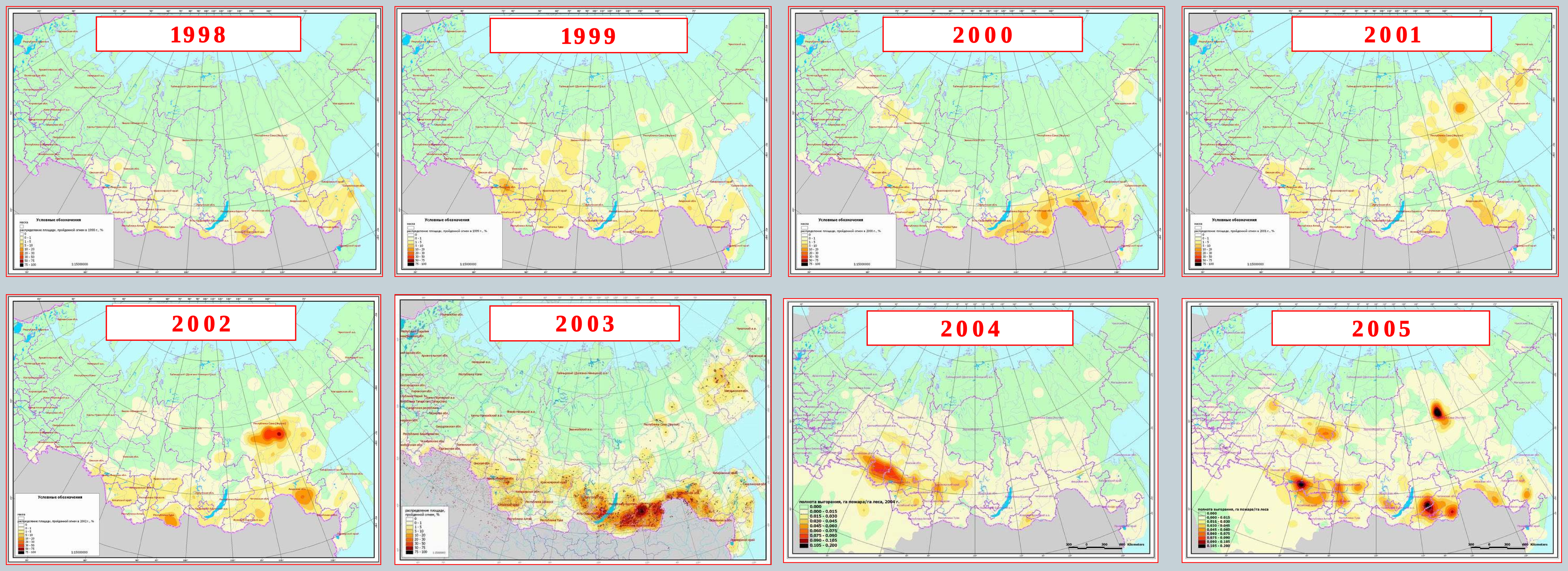
The circumpolar boreal zone has global significance in terms of climate change impacts and carbon storage. Wildfires are the dominant disturbance regime, burning 10 to 25 million hectares per year. These fires are a significant source of CO_2, as well as other greenhouse gases and aerosols. Fire activity and emissions are projected to increase substantially in the boreal zone as climate warms. Projecting the impacts of changing climate on future fire regimes and the interactions of fire with carbon storage and atmospheric chemistry under a changing climate requires baseline data on fire activity that can be coupled with weather data and emission data to quantify past fire effects. This information can then be linked to outputs of climate models and projections of potential future vegetation change to predict future burned areas, fire severity and impacts on carbon storage, carbon emissions, atmospheric chemistry and climate. We will combine recent MODIS satellite data (2001-2010) with fire records reconstructed from archived satellite imagery for 1980-2000 to develop a 30-yr fire record for Siberia. We will integrate these data with historic fire weather, emissions data, and vegetation data to estimate fuel consumption, fire severity, and emissions from fires in Siberia from 1980 to 2010. In addition, we propose using dendrochronology data to develop spatially-explicit reconstructions of past burned areas for selected sub-regions for at least the past 200 years. These data will provide insight into historic regional-scale fire/climate relationships and will allow us to place the 30-year satellite-based data in context of longer time scales. The historical relationships derived through this work will provide a basis for projecting the future effects of changing climate on fire patterns, emissions and carbon cycle in Siberia.

Research Goals

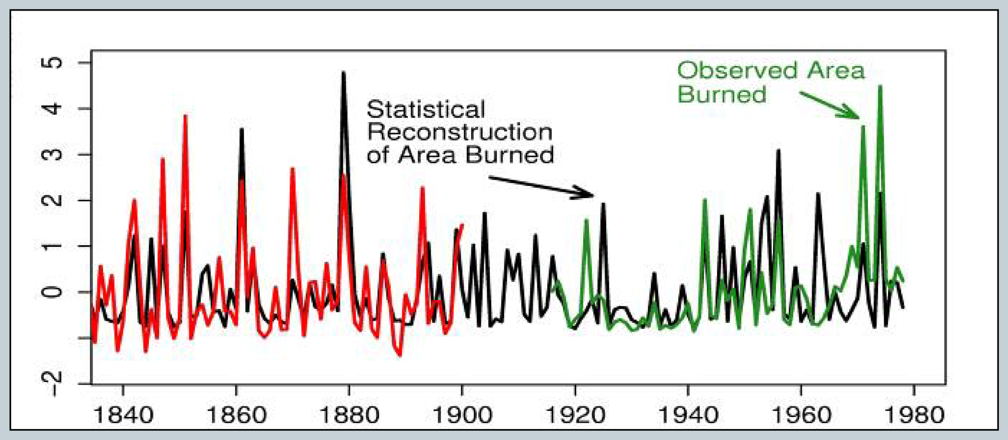
- **Complete a 30-year (1980-2010) satellite-based geospatial record of burned areas for Siberia;**
- **Integrate satellite-derived burned areas with geospatial data with models of vegetation, fuels, and fire/climate relationships to estimate fire severity, fuel consumption, emissions, and ecosystem impacts of fires;**
- **Use the 30-year burned area dataset to calibrate longer term tree-ring chronology time series of burned areas for subregions;**
- **Use both modern and paleo-fire reconstructions to evaluate relationships of fire with changing climate, variations in vegetation, and fire weather patterns to estimate historic fire emissions and impacts of fire on the carbon cycle at landscape to regional scales;**
- **Project potential impacts of climate change on burned area, fire severity and carbon cycle.**

Anticipated impacts of research

- **This project will integrate remote sensing data with experimental data and ecosystem models to quantify past and current impacts, and project potential future impacts, of wildfire in Russia under a changing climate.**
- **Critical information for input to global change models and analysis of the regional and global impacts of changing fire regimes in the boreal zone.**



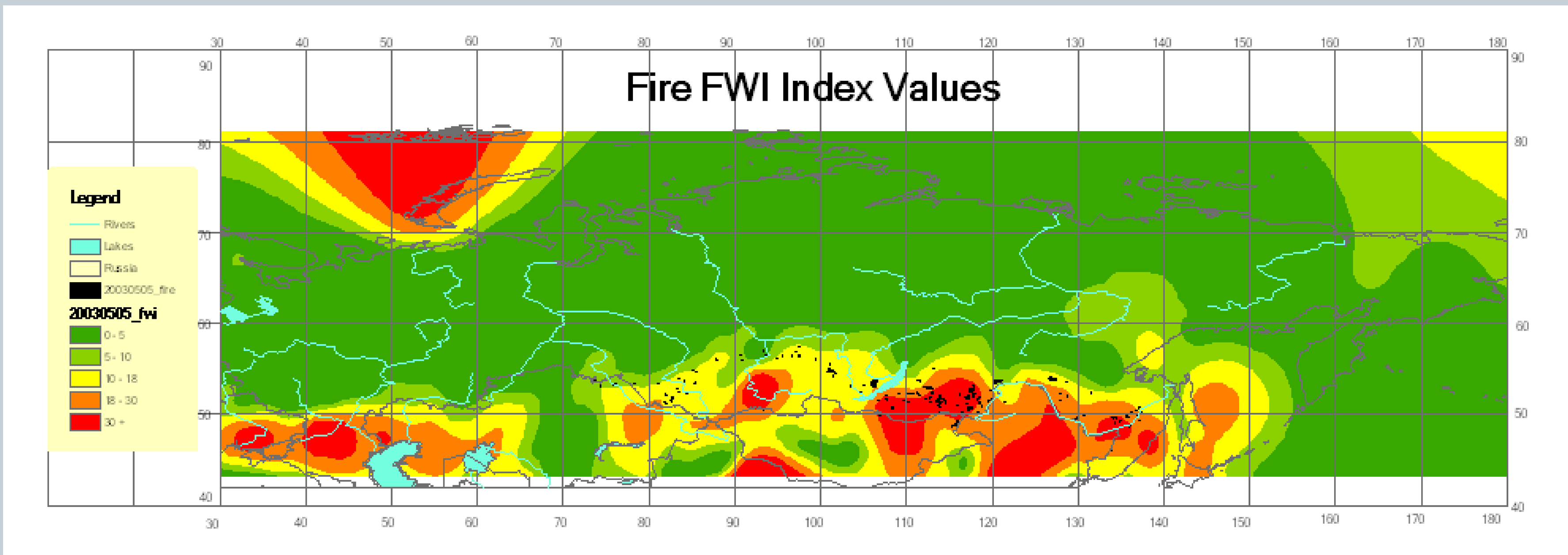
An average of 12 to 15 million ha burn annually across Russia. Annual spatial and temporal distributions of fires vary depending on regional fire danger patterns. These AVHRR-derived maps from Anatoly Sukhinin show the relative percents of burned areas in different regions from 1998 to 2005. The darker orange and red indicate higher relative burned areas.



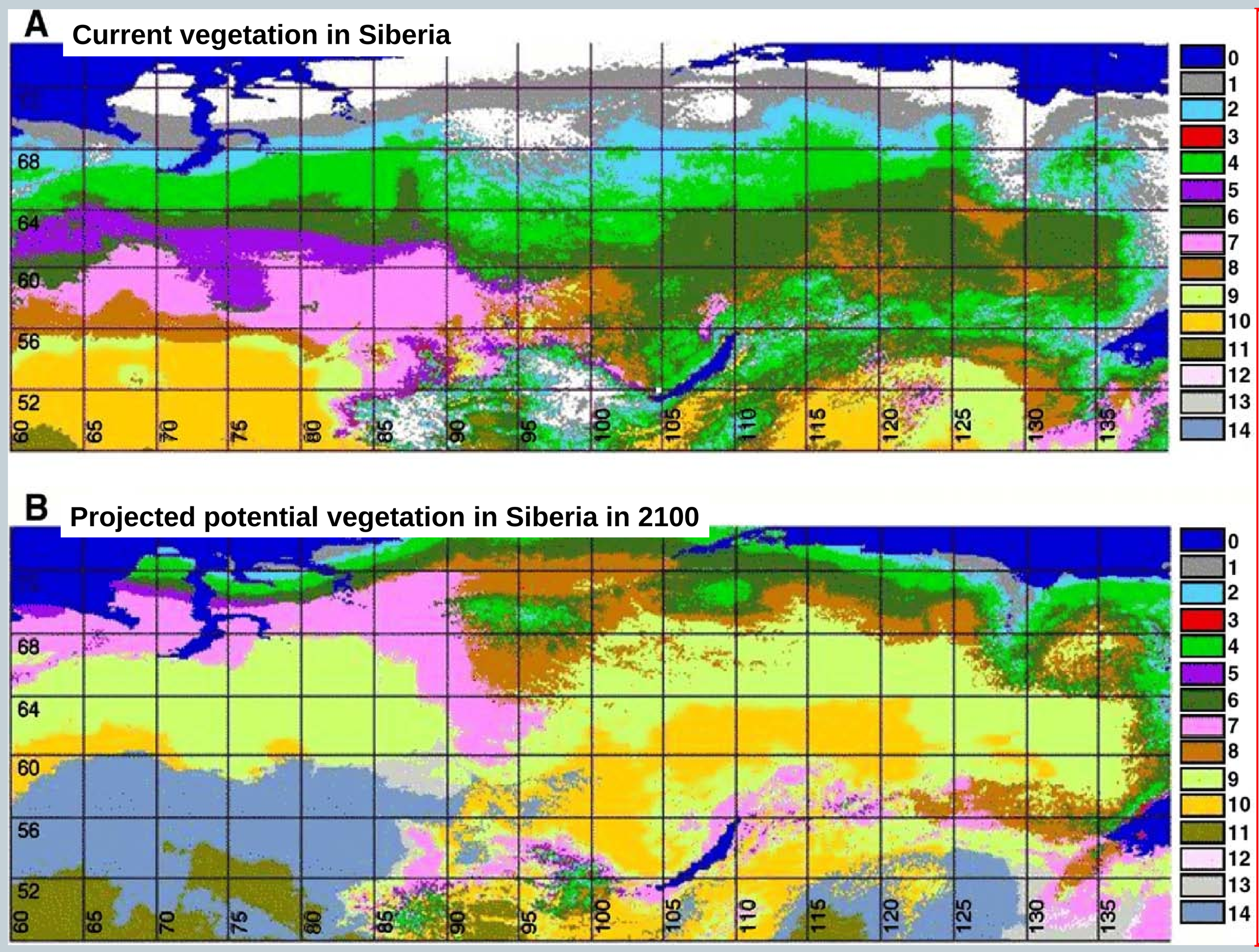
- **Westerling and Swetnam (2003) reconstructed area burned from tree-ring width chronologies (black line), calibrated this with modern area burned data (green line), and compared the reconstruction to fire-scar based data (red line) in the western US (Spearman's r = 0.61, p<0.05).**
- **We will use similar approaches to estimate past burned areas and fire/climate relationships from tree ring data and to calibrate tree ring data with remotely-sensed data on burned areas and burn severity.**

We will parameterize the Canadian Fire Effects Model (CanFIRE) for Siberia using geospatial data and models derived from this project. Initial tests have demonstrated the applicability of the Canadian Forest Fire Danger Rating System (including Fire Weather Information System) and the CanFIRE model for Siberian vegetation, fuels, fire behavior, fuel consumption and fire regimes.

CanFIRE Characteristics:
- **Stand-level fire simulation model that can be run on a single fire or simulate landscape fire regimes at annual timesteps.**
- **Incorporates impacts on major boreal tree species, standing timber, logging slash, grass, and other fuel types.**
- **Simulates live and dead biomass dynamics, fire regime impacts, emissions of C and GHGs**

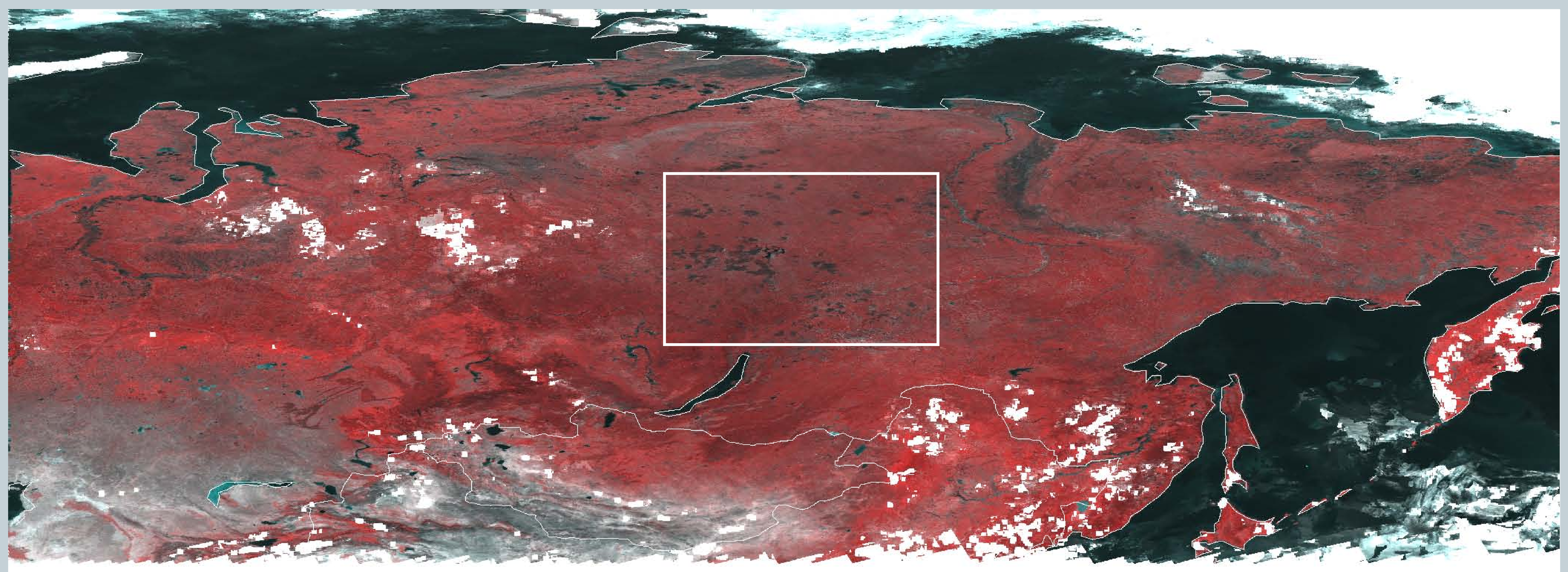


Fire Weather Index values in Siberia for 5 May 2003. Fires are shown by black polygons. High FWI is associated with areas of high fire activity. Note the high fire activity in this same area during the 2003 fire season (above). We will integrate fire weather, fuel, and vegetation models with data on fuel consumption and emissions under various conditions to estimate regional impacts of fire on carbon, GHG emissions, and aerosols. (Doug McRae)



Vegetation distribution in Siberia:
(A) current and (B) future (2100) modeled vegetation based on a Hadley scenario (HadCM3GGal) (IPCC, 1996).

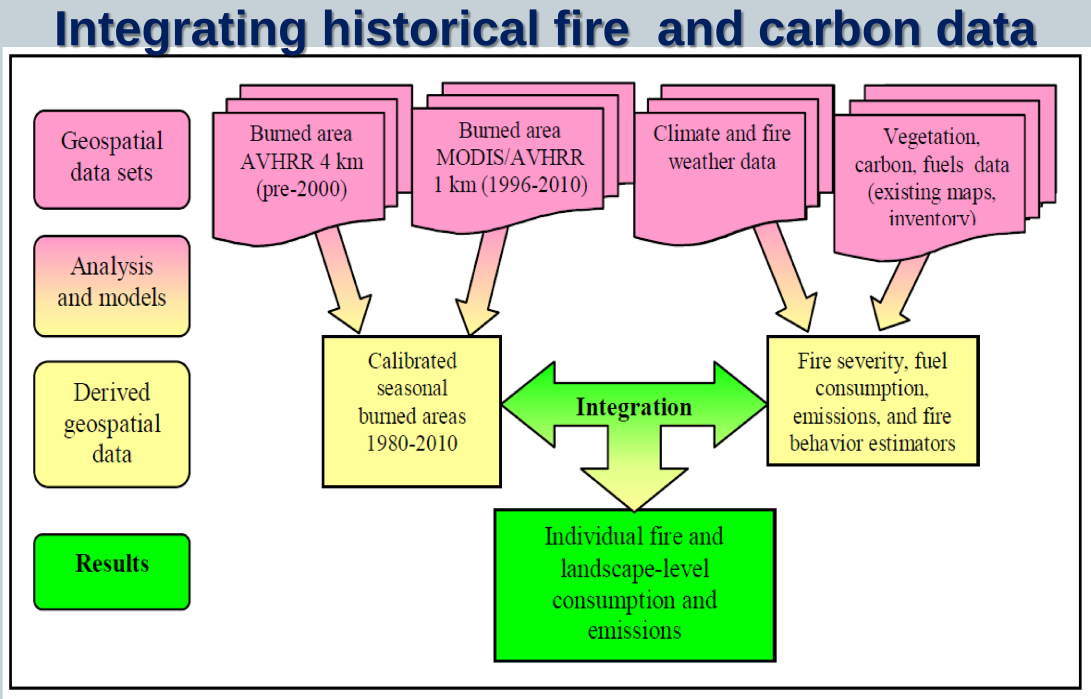
0--Water;
1--tundra;
2--forest–tundra;
3--northern dark taiga;
4--northern light taiga;
5--middle taiga;
6--middle light taiga;
7--southern dark taiga;
8--southern light taiga;
9--forest–steppe;
10--steppe;
11--semi-desert;
12--broadleaved;
13--temperate forest steppe;
14--temperate steppe .
Soja, Tchebakova et al. (2007)



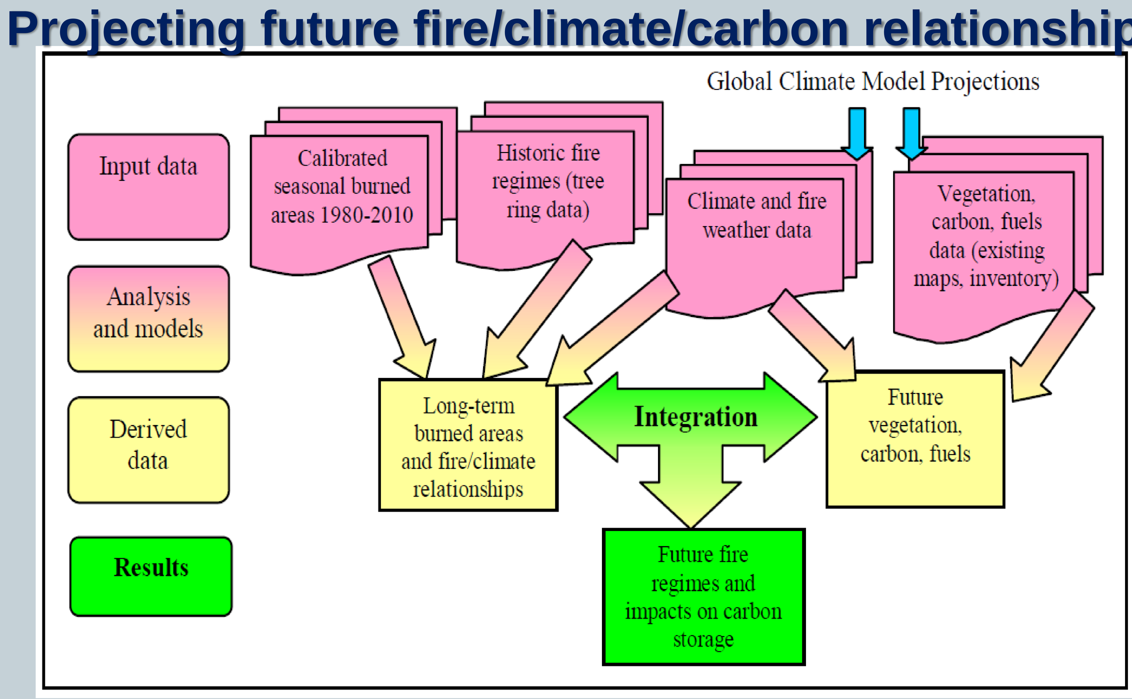
This monthly composite for August 1985 was derived from hundreds of AVHRR GAC images with smoke and cloud filters applied (Don Cahoon and Brian Stocks). We are completing a 25-year series of GAC fire-scar and emissions data for Russia. We will cross-calibrate these data with fire data from AVHRR LAC, MODIS, and Landsat. We will then overlay burned area data with geospatial vegetation, carbon and fuels data to produce a calibrated 30+ year record of burned areas, fuel consumption, and emissions.

These flow charts illustrate the data needs and integration processes for (left) developing historical data and relationships between fire, carbon, and climate, and (right) combining these data and models with climate change models and projections of potential future vegetation to project future fire regimes and their impacts on carbon stocks and emissions.

Integrating historical fire and carbon data



Projecting future fire/climate/carbon relationships



Project Team: Susan Conard (USFS)— *fire ecology and effects; scientific PI*; Wei Min Hao (USFS)— *fire remote sensing, emissions, fire weather; Institutional PI;* Brian Stocks (Wildfire Investigations, CAN)—*fire remote sensing, fire/climate interactions, smoke transport;* Don Cahoon (US)—*fire remote sensing;* Anatoly Sukhinin (Sukachev Inst., RU)—*fire remote sensing; validation;* Amber Soja (National Institute of Aerospace, US)—*fire remote sensing; fire weather; emissions; fire/climate/ecological interactions* ;Doug McRae (NRCan—CFS)—*fire behavior and fuel consumption; fire weather;*

Bill de Groot (NRCan—CFS)—*CanFIRE model; fuels and fuel consumption;* Tom Swetnam (Univ. Arizona, US)—*fire history; fire/climate interactions;* Galina Ivanova and Elena Kukavskaya (Sukachev, RU)—*fire history and ecology, decomposition;* Nadja Tchebakova and Elena Parfenova (Sukachev, RU)—*climate/vegetation modeling;* Rich Birdsey (USFS) and Vlady Alexeyev (St. Petersburg, RU)—*carbon stocks in vegetation and soils;* Mike Flannigan (NRCan—CFS)—*fire/climate interactions, fire weather.*