Improving Large-scale Biomass Burning Carbon Consumption and Emissions Estimates in the Former Soviet Union based on Fire Weather

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Fire regimes, ecosystems, fire severity and intensity vary widely, even within the same system, under the control of weather and climate, strongly influencing the amount of fuel burned and the ultimate destination of those emissions.

Motivation

Accurately estimating the amount of biomass burned during fire events is challenging, particularly in remote and diverse regions, like those of the Former Soviet Union (FSU). Historically, we typically assumed 25 tons of carbon per hectare (tC/ha) burned, however depending on the fuel contained in the ecosystem and fire severity, biomass burning emissions can range from 2 to 75 tC/ha (Soja et al., 2004). Subsequently, the depth of burn in particular ecosystems is under the control of the precipitant weather that controls the dryness of the fuels.

Poster Goal

We show the parameters that define the hybrid maps and the relationship between fire weather (precipitation, temperature, relative humidity and wind speed) (Van Wagner, 1987) and fire regimes.

Crown and medium-severity boreal forest fires.

Photo: BJ Stocks

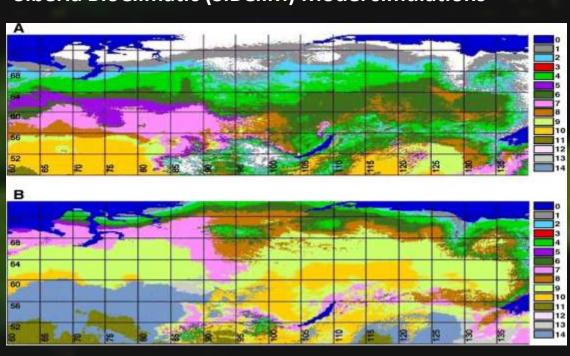These are all boreal forest, demonstrating the variety of fuels and fire regimes.

Boreal forest hold the largest pool of terrestrial, and Russian forests account for 2/3 of this expanse. Ecosystems in the FSU span from the tundra through the taiga to the forest-steppe, steppe and deserts and include the extensive West Siberian lowlands, permafrost-lain forests and agricultural lands. Excluding this landscape disparity results in inaccurate emissions estimates and incorrect assumptions in the transport of these emissions Apps et al., 1993; Alexeyev and Birdsey, 1998).

Climate- and weather-driven change in fire regimes are catalysts for ecosystem change.

Climate and fire regimes are predicted to change and are already changing in these systems.

Siberia BioClimatic (SiBCliM) Model simulations

Vegetation distribution in Siberia: (A) current and (B) future (2100) based on a Hadley scenario (HadCM3GGal) (IPCC, 1996). Water (0), tundra (1), forest–tundra (2), northern dark taiga (3) and light taiga (4), middle dark taiga (5) and light taiga (6), southern dark taiga (7) and light taiga (8), forest–steppe (9), steppe (10), semidesert (11), broadleaved (12), temperate forest–steppe (13) and temperate steppe (14).

Tchebakova et al (2009, 2010, 2011)

* It is predicted the taiga will largely be replaced by steppe and forest-steppe ecosystems in Siberia.

* There is already evidence of the migration of keystone ecosystems in the upland and lowland treeline of mountainous regions across southern Siberia (Soja et al., Global and Planetary change, 2007). This change is often precipitated by large fire events.

Evolution of a Hybrid Ecosystem Map of the Former Soviet Union to include a range of carbon consumption estimates

Why a hybrid map

The Former Soviet Union is expansive and represents a wide range of ecosystems that contain carbon pools that can vary by orders of magnitude. Recently, Kukavskaya et al. (in press) found that biomass burning emissions can vary by up to 5-fold.
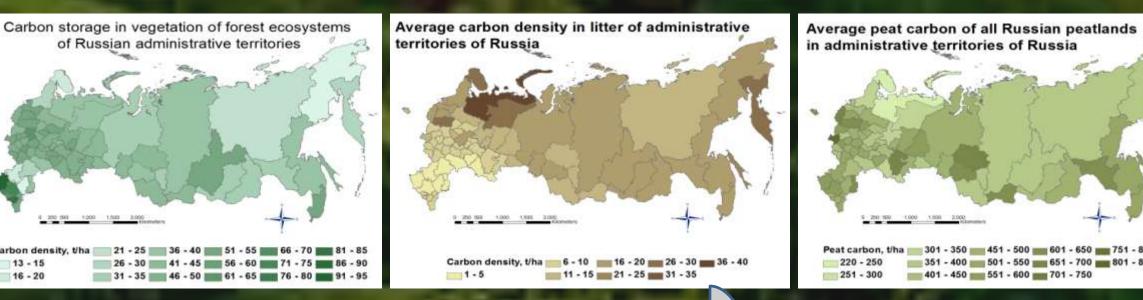
Additionally, this is a region where extensive knowledge about the carbon contained in these systems exist and also a region that has been significantly altered. By taking advantage of the existing carbon databases and relatively new remotely sensed data, we can immensely improve our knowledge of the carbon balance of these diverse ecosystems, hence improve estimates based on this knowledge (i.e. biomass burning emissions).
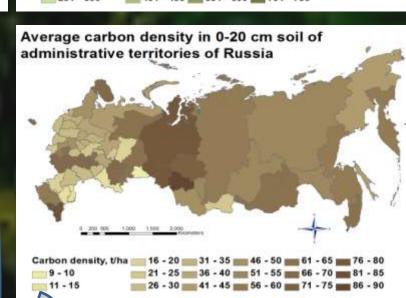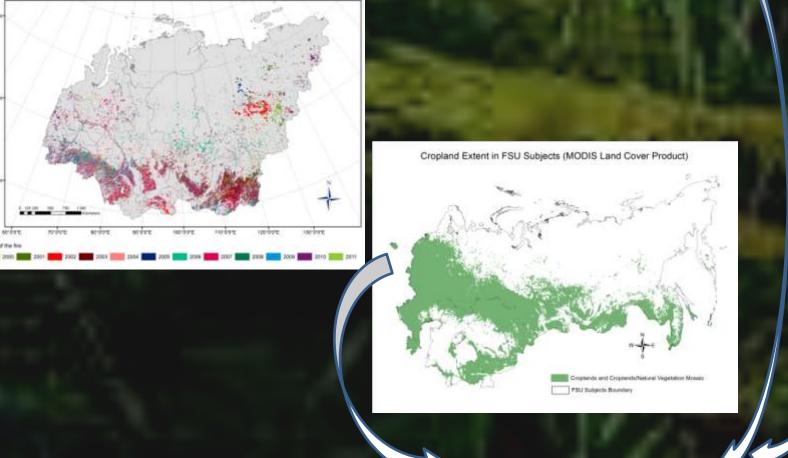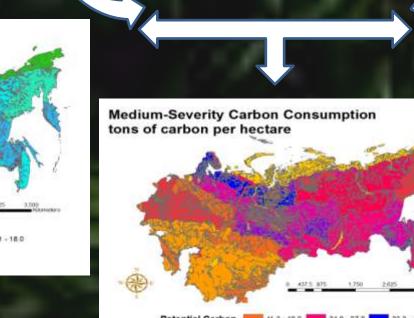
Ecoregions of the Former Soviet Union
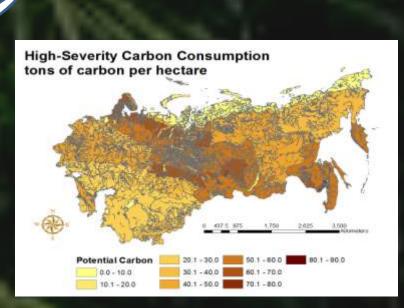
Methodology I

Building from previous work (Soja et al., 2004, Conard et al.), Geographic Information Systems is used to integrate: ecosystems; Alexeyev and Birdsey (1998) carbon data; MODIS croplands and Urban areas; and burned area to generate a range of carbon consumption maps, which will be paired with MODIS fire data and emissions factors to estimate the variety of fires that burn across the landscape.
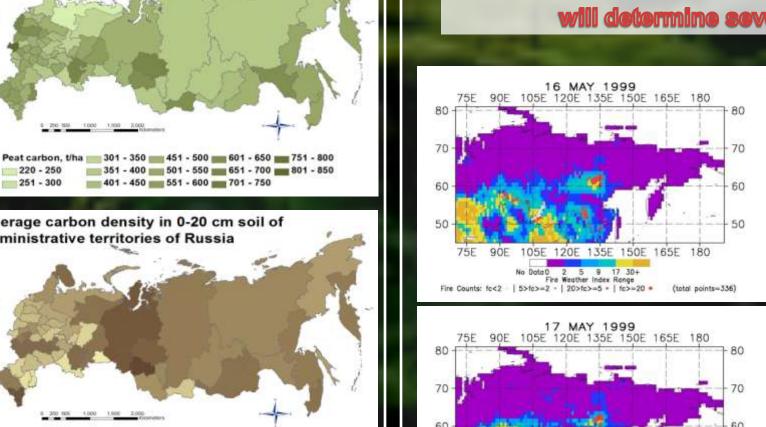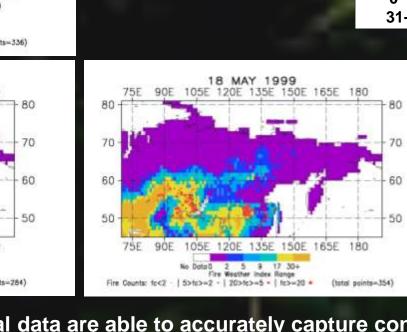
Carbon storage in vegetation of forest ecosystems of Russian administrative territories

Average carbon density in litter of administrative territories of Russia

Average peat carbon of all Russian peatlands in administrative territories of Russia

Ecosystems control the amount of potential fuel.

Average carbon density in 0-20 cm soil of administrative territories of Russia

Cropland Extent in FSU Subjects (MODIS Land Cover Product)

Low-Severity Carbon Consumption tons of carbon per hectare

Medium-Severity Carbon Consumption tons of carbon per hectare

High-Severity Carbon Consumption tons of carbon per hectare

Climate → Weather → Available Fuel → Injection height

Surface fire

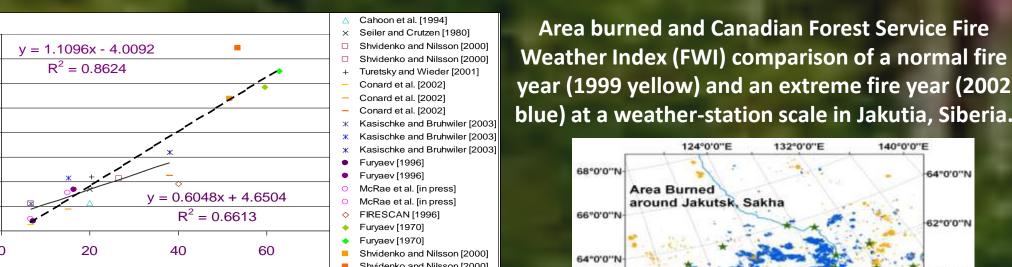5-6 km Courtesy P3 group

10 km Courtesy Mr. Todo, JAL

Methodology II

Fire Weather determines the precipitant fuel conditions, which is directly related to how much fuel is available to burn. These data will be used to drive the model.

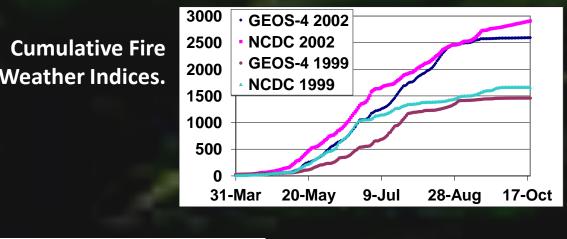$y = 1.1096x - 4.0092$
$R^2 = 0.8624$

$y = 0.6048x + 4.6504$
$R^2 = 0.6613$

Estimates of ecosystem- and severity –dependent carbon consumption compare well to experimental data.

Fire Weather will determine severity

Area burned and Canadian Forest Service Fire Weather Index (FWI) comparison of a normal fire year (1999 yellow) and an extreme fire year (2002 blue) at a weather-station scale in Jakutia, Siberia.

Area Burned around Jakutsk, Sakha

1999
2002
Lena river
NCDC station

In boreal regions, fire weather is directly related to the potential severity of a fire, hence the amount of fuel consumed.
** The extreme year separation in this case occurs at ~ 1500.

Cumulative Fire Weather Indices.

GEOS-4 2002
NCDC 2002
GEOS-4 1999
NCDC 1999

Canadian Fire Weather Index, derived using large-scale (1°) NASA Goddard Earth Observing System (GEOS-4) and Global Precipitation Climatology Project (GPCP) meteorological variables, overlaid with fires in red.

16 MAY 1999
17 MAY 1999
18 MAY 1999

Large-scale meteorological data are able to accurately capture continental-scale patterns of large and small fire events using fire weather data.

Together, accurately representing the amount of fuel contained in an ecosystem and the amount that is dry enough to burn results in an more accurate carbon accounting and biomass burning emissions estimates.

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