Modeling the disturbance of vegetation by fire in the boreal forest

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Introduction

Boreal regions are important for the global carbon cycle because it is the largest forested area on earth. Moreover, the largest warming trends over the globe over the last decades have been observed in these regions and changes of the land ecosystems have already started. A major factor that determines the structure and carbon dynamics of the boreal forest is fire. As fire frequency depends strongly on climate, increased fire occurrence and related losses to the atmosphere are likely. Fire models may be used to study the evolution of fire, vegetation and climate feedbacks in boreal forests in the context of global warming.

Fire models are based on the following equation that gives the amount of carbon emitted directly to the atmosphere by fires in a grid-cell (x,y) at time t:

$$\text{Emis}(x,y,t) = \sum C \times \text{Fuel}(x,y,t) \times BA(x,y,t)$$

-We present here a prognostic model that estimates monthly BA in grid cells of 2°×2.5° from climate and human-related variables. This model will be coupled to LM3V, the new vegetation model of GFDL, to study the disturbance of vegetation by fire in the boreal forest.

How fires are related to climate and human-related variables?

Comparison of on-ground observations of fire in the Canadian boreal forest [Stocks et al., 2003] with climate and human related variables:

-Use of:
  - Temperature (T), relative humidity (RH) and wind (W)
  - Observed precipitation (Nijssen et al., 2001)
  - Soil water content (W) from LM3V
  - Road density (Ro)

Clear separation of fire events from general situations.

-ESTIMATION OF BURNED AREA (BA): a prognostic fire model:

$$BA = \alpha \prod_i \frac{1}{1 + \exp[-(\beta_i \times x_i + \mu_i)]}$$

where $x_i \in [T, RH, Pr, W, Ro]$

The estimation of the 11 parameters (a and 5 $\mu_i, \beta_i$) is performed on the Canadian large fire database [Stocks et al., 2003], using an MCMC method.

-precipitation and temperature are the two main drivers of fire.
-All factors, except wind, are of the same order of importance.

In order to evaluate the fire model in a stand-alone approach (ie, without vegetation), the history of fires is taken into account according to the following equation:

$$\text{Estimated BA for year } t+1 = \frac{\text{BA}_t \times S - \text{BA}_t}{S - \text{BA}_t}$$

Burned area in three boreal regions

- Boreal forests in Canada:

- Boreal forests in Siberia:

- Boreal forests in Alaska:

Conclusions

- The model is able to reproduce the seasonality of fire, the interannual variability, as well as the location of fire events, not only for Canada (on which the data model is based), but also for Siberia and Alaska.
- The results compare well with remote sensing observation, and are in the range of various current estimations of burned area.
- The fire model is being implemented in LM3V, the new vegetation model of GFDL, in order to make prediction of future fire behavior in boreal regions, and of related disturbance of the vegetation and carbon emissions.

References

Stocks et al., Large fire events in Canada (1950-1997), JGR, 2003.