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:

$$Emis(x,y,t) = \sum_i C_i \times Fuel_i(x,y,t) \times BA(x,y,t)$$

combustion efficiency (C_i) — available biomass (vegetation model) ($Fuel_i$) — burned area (estimation) (BA)

•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:

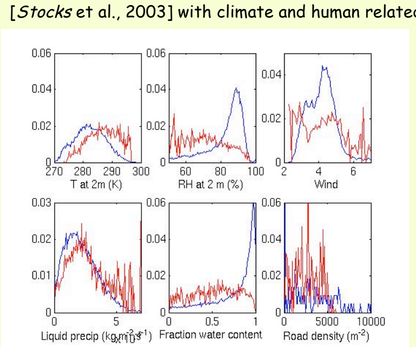

Fig. 1 - Normalized histograms of fire and no-fire situations

•Use of:
- ✓Temperature (T) , relative humidity (RH) and wind (Wi) from AM2p14 simulations [*Anderson* et al., 2004].
- ✓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:

$$BA = \alpha \prod_i \frac{1}{1+\exp\left[-(\sigma_i \times x_i + \mu_i)\right]} \qquad x_i \in \{T, RH, Pr, W, Ro\}$$

The estimation of the 11 parameters (α and 5 μ_i,σ_i) is performed on the Canadian large fire database [*Stocks* et al., 2003], using an MCMC method.

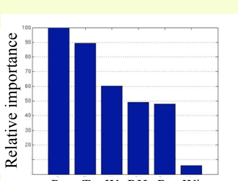

Fig. 2 - Relative importance of each variable in the estimation of BA

⇨ •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:

$$\overline{BA}_{t+1} = BA_{t+1}^{\text{mod}} \times \left(\frac{S-\overline{BA}_t}{S}\right)$$

Estimated BA for year t+1 ($\overline{BA}_{t+1}$) — Model output for year t+1 (BA_{t+1}^{mod}) — Surface of a grid-cell (S) — Estimated BA for year t ($\overline{BA}_t$)

Burned area in three boreal regions

•**Boreal forests in Canada**:

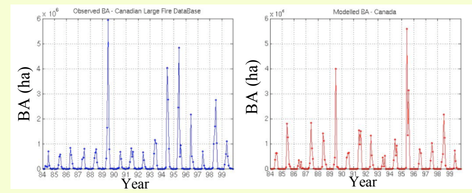

Fig. 3 - Observed (left) and estimated (right) monthly burned area in Canada

⇨ Seasonality and major fire events are retrieved by the model.

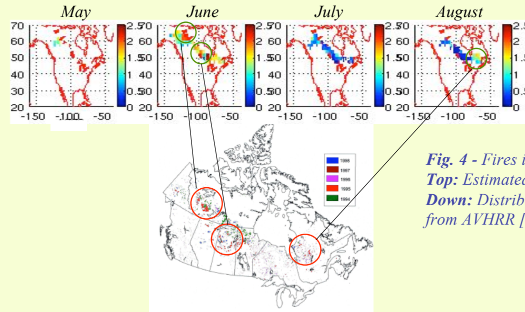

Fig. 4 - Fires in 1995.
Top: *Estimated monthly BA*
Down: *Distribution of fire spots from AVHRR [Li et al., 2000]*

•**Boreal forests in Siberia**:

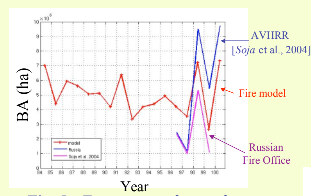

Fig. 5 - Time series of annual BA in boreal forest of Siberia

⇨ The seasonality of fire in Siberia is well captured by the model. The amplitude is in the range of current estimations.

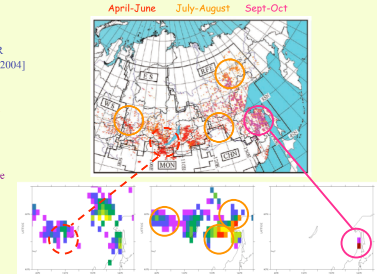

Fig. 6 - Fires in Siberia in 1998.
Top: *Monthly distribution of fire spots from AVHRR [Kajii et al. 2002].*
Down: *Estimated monthly BA*

•**Boreal forests in Alaska**:

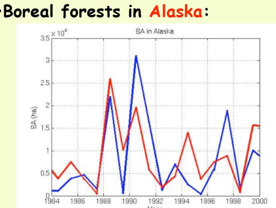

Fig. 7 - Time series of annual BA in boreal forest of Alaska, observed [Alaska Fire Service] and estimated.

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 data the 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

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