Simulation of vegetation dynamics in eastern boreal North America during pre-industrial times using LPJ-LMfire

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Context

The climate is changing and so are Canada’s forest

Some uncertainties...

1. Natural variability

2. Paleoecology
   - Weight of drivers
   - Local processes
   - Costly
   - Time-consuming
Objectives

- Present advances made in the deployment of a DGVM to simulate at high spatiotemporal resolution the responses of vegetation and fire to changes in climate during the last 6000 years;
- Discuss the performance of the model at multi-millennial time-scales.

The tool used:

4 PFTs: Picea, Abies, Pinus, Populus

Chaste et al. 2018
LPJ-LMfire

Methodology

Inputs
- Climate
- Weather generator
- Constraints

Outputs
- Biomass
- NPP
- Fire
- % cover

Daily processes
- Soil hydrology
- Stomatal regulation
- Photosynthesis
- Plant respiration
- Leafs-roots phenology
- Decomposition

Annual processes
- Biomass allocation & growth
- Reproduction
- Establishment
- Mortality
- Leafs-roots-wood turnover

ECOSYSTEM
Input datasets
(6000 BP – 0 BP)

Climate = 7 variables

Environment = 4 variables

10 km x 10 km
Input datasets
(6000 BP – 0 BP)

Climate = 7 variables

Directly from the French Pierre-Simon-Laplace Institute Earth system model IPSL-CM5A-LR (1.875° x 3.75°)

Reconstruct the monthly lightning flash density (number day⁻¹ km⁻²) from 6000 to 0 BP from the convective available potential energy (CAPE) available for the IPSL-CM5A-LR using the same methodology in Chaste et al. 2018
LPJ-LMFIRE: BIOMASS

Results

cal. k-yrs BP

(A) Biomass (T/ha)

6 - 5
5 - 4 +
4 - 3 ++
3 - 2 ++
2 - 1 +
1 - 0 +
Results

LPJ-LMfire: FIRES

cal. k-yrs BP

(A) Biomass (T/ha)

(B) Annual Burn Rates (%)

1 - 0 +

2 - 1 +

3 - 2 ++

4 - 3 +++

5 - 4 ++

6 - 5 +

(B) Annual Burn Rates (%)

0

0.1

0.2

0.3

0.5

3.0

> 3.0

(B) Annual Burn Rates (%)

0

5

10

20

40

60

80

100

> 100

(A) Biomass (T/ha)
LPJ-LMfire: GROWTH

Results

cal. k-yr BP

6 - 5

5 - 4 ++

4 - 3 +++

3 - 2 ++++

2 - 1 +

1 - 0 +

(A) Biomass (T/ha)

0
5
10
20
40
60
80
100
> 100

(B) Annual Burn Rates (%)

0
0.1
0.2
0.3
0.5
3.0
> 3.0

(C) NPP (T/ha/yr)

0
1.5
3.0
4.5
6.0
7.5
9.0
> 9.0
LPJ-LMfire

Results

cal. k-yrs BP

6 - 5

5 - 4 +

4 - 3 ++

3 - 2 ++

2 - 1 +

1 - 0 +

West

Temperature anomalies (°C)

Age (cal. k–yrs BP)

Annual Spring Summer

Genus–specific PFT

Picea Abies Pinus Populus

Cumulative cover percentage

Age (cal. k–yrs BP)
LPJ-LMfire

Results

cal. k-yrs BP

6 - 5
5 - 4 +
4 - 3 ++
3 - 2 ++
2 - 1 +
1 - 0 +

Temperature anomalies (°C)
Age (cal. k-yrs BP)

Genus-specific PFT
- Picea
- Abies
- Pinus
- Populus

Coniferous
Populus

Cumulative cover percentage

Age (cal. k-yrs BP)
Results

LPJ-LMfire : validation

Comparison of LPJ-LMfire model simulations with reconstructions obtained from pollen and lacustrine-charcoal records
LPJ-LMfire: validation

With lacustrine-charcoal records
Results

**LPJ-LMfire : validation**

*With pollen records*

![Graph showing observed and simulated total tree biomass (T/ha) over different ages (cal. k-yrs BP).]
LPJ-LMfire: validation

To keep in mind (1):

- The first study: Holocene vegetation dynamics simulations with high spatial and temporal resolution in eastern boreal Canada;

- Long-term regional climate largely influences the vegetation dynamics: warm growing seasons at 6000 BP allowed a rapid vegetation establishment in the east, whereas cold spring temperatures have limited biomass growth in the west;

- Vegetation acts as an important "bottom-up" control on fire frequency at long time-scales.
To keep in mind (2):

- Low biomass and high *Populus* cover percentage contributed to low simulated fire activity;

- Simulated trajectories in fires and vegetation changes during the last 6000 years were not entirely synchronous with reconstructions of fire frequency and tree biomass: LPJ-LMfire simulations captured the changes in forest dynamics further south in the west and further north in the east compared to the empirical data;

- We suggest that the discrepancies between simulated and observed trajectories are associated to uncertainty in the IPSL-CM5A-LR climate dataset that has been used as an input to LPJ-LMfire.
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Questions?