Modeling carbon dioxide exchanges in the newly flooded black spruce forest and peatland using a process-based reservoir model

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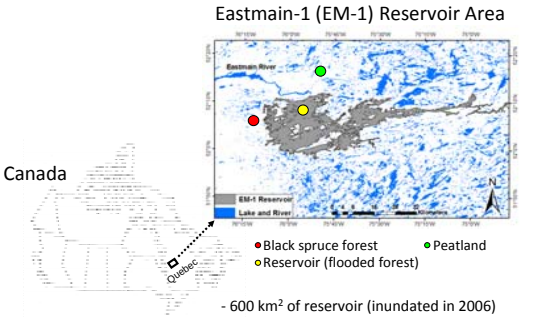
Introduction

- Creation of a hydroelectric reservoir results in dramatic changes of carbon (C) exchanges compared to pristine ecosystems, mainly caused by the change from a terrestrial to aquatic ecosystem (Rosenberg *et al.* 2000) – Questions whether hydroelectric reservoirs are negligible global sources of carbon dioxide (CO_2) and methane (CH_4). However, C exchanges from reservoir surfaces are poorly understood because previous research relied on irregular or sporadic field measurements – Ecosystem modeling can help to increase our understanding of the C exchanges and why and how they change with flooding.
- Forest-DNDC (Miehle *et al.* 2006), able to follow changes in redox chemistry, is the ecosystem model we adapted to simulate the C flux change due to flooding. To use Forest-DNDC for the flooded ecosystems, we first evaluated its ability to simulate undisturbed ecosystems and then modified this model for use in flooded conditions.
- The study objectives are to: (1) Adapt a process-based terrestrial model to estimate ecosystem-level C exchanges in flooded boreal forests and peatlands; (2) Compare the C exchanges in boreal forests and peatlands between pre-flooded and flooded conditions using simulations of C flux; and (3) Project changes of C exchanges of flooded boreal forests and peatlands for the possible life time of inundation (i.e. 100 years).

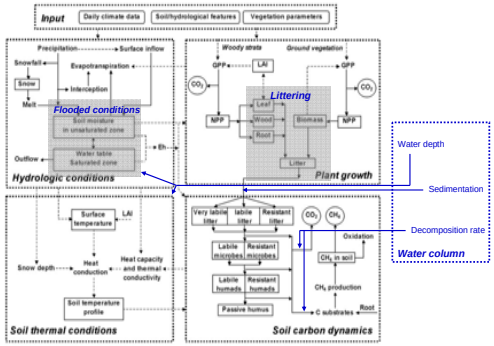
Study sites



- 600 km² of reservoir (inundated in 2006)
- 65% forest; 14% peatland; 21% lake and river
- Eddy-covariance tower measurement at each site

"Flooded" version of Forest-DNDC

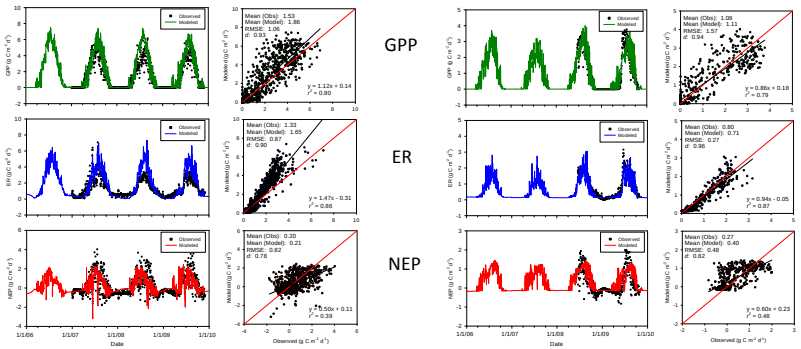
- Forest-DNDC has been used to study upland/wetland C and N cycling and employs redox chemistry in soil – Useful for the flooded ecosystem.
- Flooded Forest-DNDC represents plant and soil C processes with complete flooding – No plant PSN/respiration; living biomass to litter; new decomposition rate; benthic temp.



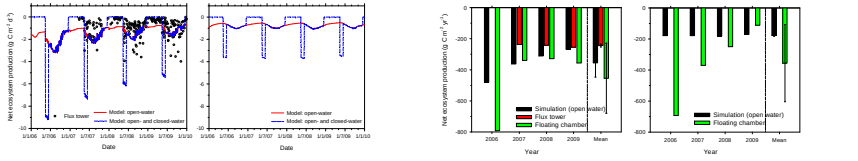
Conceptual diagram of Flooded Forest-DNDC (adapted from Zhang *et al.* 2002)

Results

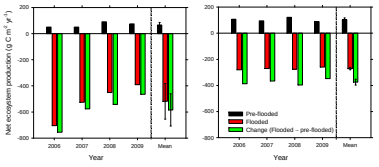
- Evaluation of Forest-DNDC simulations over the natural ecosystems (2006–2009)
  - Daily C flux in black spruce forest
  - Daily C flux in peatland



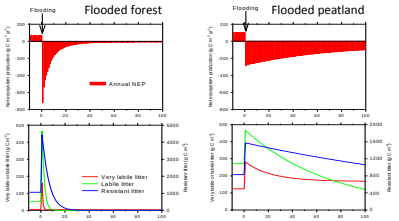
- Flooded Forest-DNDC simulations over the flooded ecosystems (2006–2009)
  - Daily NEP: flooded forest (left) and peatland (right)
  - Annual NEP: flooded forest (left) and peatland (right)



- Change of C exchange: from natural to flooded conditions (2006–2009)
  - Annual NEP: flooded forest (left) and peatland (right)



- Projection of C exchange over 100 years



Discussion

- Forest-DNDC produces reasonable estimates of the C flux in the mature black spruce forest and peatland – Used as the "Reference" C exchanges for natural conditions of boreal terrestrial ecosystems.
- Over the flooded ecosystems, the decreasing daily or annual C fluxes is due to a reduction in the availability of more degradable organic matter in the flooded soils.
- Over the flooded ecosystems, disagreements between daily and annual NEP in the tower or chamber measurements and simulations are associated with underestimations of the modeled outputs due to the absence of aquatic production and respiration and uncertainty in how to relate the measured fluxes to physical and/or biogeochemical processes.
- Our simulations can project the potential difference between C fluxes from pristine and flooded boreal terrestrial ecosystems.
- The 100-year simulations show dramatic reduction of the C emissions from flooded forest but less reduction in the flooded peatland because peatlands contain larger amounts of decomposable C in the peat.

References

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