EM-1 PROJECT *Reservoirs' net greenhouse gas emissions research project*

Changes in Scale Net Greenhouse Gas Emissions Due to Land Cover Changes Associated with the Creation of Reservoirs for the Production of Hydroelectricity

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Project Description

Background:

There are two major sources of greenhouse gas (GHG) emissions due to human activities: direct emissions from the burning of fossil fuels for energy production and indirect emissions resulting from the conversion of land cover types or land-uses that are sinks and/or stores of carbon. These two sources of CO_2 to the atmosphere are approximately 5 to 6, and 1 to 2 Pg C yr^{-1}, respectively. In order to satisfy present and future energy demand linked to increasing economic and population growth, and to reduce GHG emissions and climate change impacts, there is a need to invest in large non-carbon based forms of energy. Hydroelectricity can produce much energy and is not based on combustion. Canada still has much potential for increasing this mode of production. Hydroelectricity production in many cases requires the creation of reservoirs that inundate terrestrial ecosystems. It has been established that reservoirs emit GHGs, but what has not been established is "what is the net change in the exchange of GHG that has resulted directly from the creation of the reservoir?"

Objectives:

1) Quantify the carbon stocks and GHG exchanges (CH_4, CO_2 and N_2O) of the pre-flooded (forests, peatlands, lakes) and post-flooded (Easmain-1 reservoir) ecosystems using eddy covariance and chamber measurements.
2) Determine the net difference between the landscape scale exchange of GHGs before and after the creation of the Eastmain-1 reservoir and how that net difference changes over time.
3) Adapt existing ecosystem models to simulate the inter-annual net ecosystem exchange for the land cover types that are flooded by the reservoir.
4) Obtain a first-order estimate of the net change in GHG exchange due to reservoir creation and longer term estimates under present and future climate conditions.

Figure 1. Eastmain-1 study site. The power house is located about 800 km north of the city of Montréal and is equipped with three turbines generating 160 MWh each for a total of 480 MWh. The main dam along with 33 dikes forms the Eastmain-1 reservoir with a surface area of 603 km^2. The impoundment began in November 2005 and was filled 7 months later. About 65% of the flooded area was occupied by boreal forests, 14% by peatlands, and 21% by lakes and rivers.

Eddy Covariance Tower Flux Measurements

This part of the project aims to measure continuous full-year CO_2 fluxes using the eddy covariance (EC) technique. In order to assess the impact that the creation of the reservoir had on the GHG emissions, we chose site locations that were representative of the pre-flooded (i.e. forest and peatland) and post-flooded (i.e. reservoir) environments. Permanent EC towers were installed in a mature black spruce-dominated forest having similar characteristics to the pre-flooded surface (Figure 3b) and on the edge of an island to acquire trace gas measurements from the reservoir itself, thus representing the post-flooding conditions (Figure 3a). These EC systems were installed and operational by the end of summer 2006. The forest EC system is mounted at 23 m height, and the reservoir EC system is mounted at 13 m above the mean water surface. A portable EC tower is used to make CO_2 flux measurements in a peatland at 2 m height, representing the second dominant pre-flooded terrestrial ecosystem type.

To provide an accurate assessment of the net GHG emissions, it is essential to compare the various techniques used for trace gas measurement from reservoirs. Gas flux measurements obtained from smaller spatial and discrete temporal scales using chambers will be compared with the results obtained for the EC towers, which provide continuous and spatially-averaged measurement of the vertical exchange over a relatively large footprint. Combined with ancillary measurements of meteorological and ecosystem variables, we will be better placed to understand the gas exchange response to changes in environmental conditions and to examine the dominant controlling factors on the CO_2 fluxes at the different study sites.

Figure 3. (a) Eddy covariance tower on the island measures fluxes over the EM-1 reservoir and (b) eddy covariance tower in the black spruce forest.

Terrestrial Aspects

The main objective of this portion of the project is to quantify CO_2 and CH_4 fluxes and the amount of carbon in terrestrial ecosystems in comparison to the flooded ecosystems.

Quaternary surficial deposits mapping of the Eastmain-1 region was done to characterize the glacial and post-glacial sediments and estimate their potential contribution, based on their $CaCO_3$ and $CaMg(CO_3)_2$ content, to CO_2 emissions from the Eastmain-1 reservoir.

Greenhouse gas flux measurements were made on the Eastmain-1 region peatlands using static chambers installed on the peat surface. Prior to reservoir creation, six peatlands were selected, three inside and three outside the reservoir area, and CH_4 and CO_2 measurements were made on the different vegetation types found, following a hydrological gradient from hummock to pools. In the same six peatlands, 31 peat cores were collected from which long term peat and C accumulation rates were determined. Macrofossils and Testate Amoeba analyses made on these cores provided indications about past climate conditions (temperature and precipitation) that influenced carbon accumulation. Ground Penetrating Radar (GPR) profiles provided peatland basin topography and, combined with C content obtained from peat cores, allowed determination of the volume of peat and C stored in the different peatlands of the region. Present-day and past conditions for carbon accumulation will be modeled using the Holocene Peat Model (Frolking, Roulet, Yu and McDonald).

Figure 2. Flux measurements in the peatland

The total amount of C stored in forest soils of the Eastmain-1 region was also measured. Five forest types were selected as representative of the region based on a remote sensing forest classification by Environment Canada (Grenier et al. 2007): closed and open coniferous forest, deciduous (aspen), recent and old burned sites. Total soil organic carbon, mineralization rates and seasonal heterotrophic respiration were determined. Results will be transferred to the regional scale using Landsat mapping.

Modeling Aspects

Ecosystem modeling is the most promising method available to understand spatial heterogeneity and long-period changes of biogeochemical cycles. Modeling is being used in the present study to answer two key questions: 1) what are the changes in C fluxes over a long-time scale (over 100 years) in boreal forests and peatlands following flooding and 2) what is the net difference in landscape C fluxes in these terrestrial ecosystems between pre- and post-flooding. To answer these questions, we will develop a process-based ecosystem model for reservoir C cycling, apply ecosystem models for C simulations of the ecosystems with and without flooding, and examine the changes in long-term C fluxes in an area covering the whole reservoir following water impoundment. By using ecosystem models, reliable estimates of C flux from the pre-flooded and reservoir ecosystems can be obtained which lead to better understanding of reservoir C cycles. The little research done on simulating reservoir C fluxes to date has focused on short-term simulations based on simple budget or mass balance approaches without consideration of reservoir C processes. This study has an innovative approach in that it will create a process-oriented ecosystem model for reservoir biogeochemistry, as well as attempting C simulation over long time periods in terrestrial ecosystems before and following water impoundment.

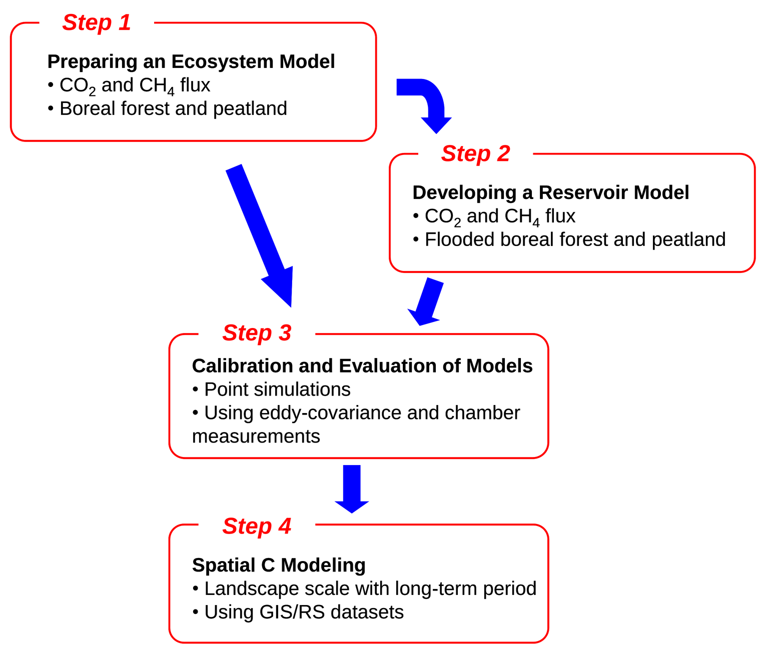

Figure 4. Procedure of modeling study

The modelling aspect of the project involves four steps (Figure 4): preparing a model for the pre-flooded ecosystems (Step 1), developing a reservoir ecosystem model (Step 2), calibration and evaluation of these models (Step 3), and spatial C modeling during the study period (Step 4). Forest-DNDC (Dr. C. Li, University of New Hampshire) has been chosen for the carbon simulation of the pre-flooded ecosystem within this study because it incorporates routines for redox chemistry related to O_2 availability and production of DOC. A new reservoir model based on modifications to Forest-DNDC will be created for the simulation of the post-flooded ecosystem. This model will be derived from modifications of parameters representing changes to environmental factors (e.g. temperature, pH, and O_2) in soil, physiological function of biomass, and movements of the C pool relevant to DOC diffusion in biomass/soil/water, as well as including a simple module of aquatic microbial metabolism governing C processes in the water column (Figure 5).

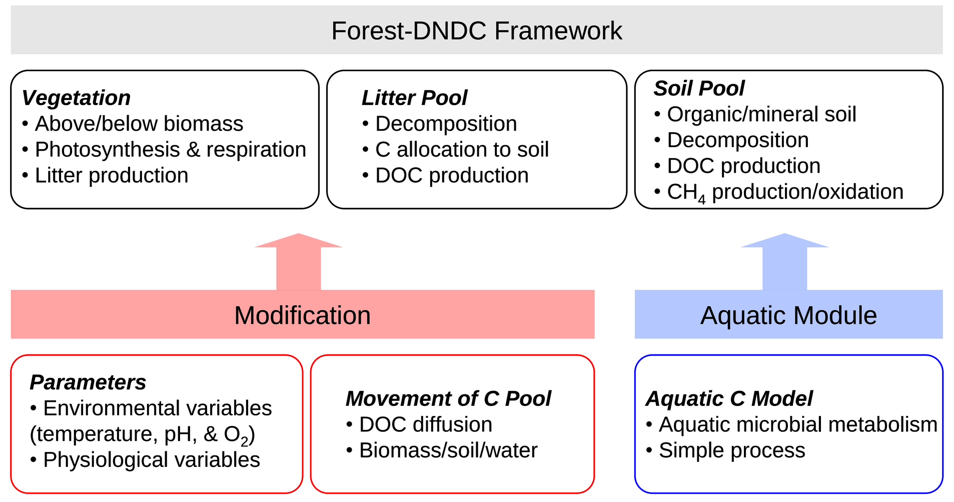

Figure 5. Model framework of the reservoir model

Reference:

Grenier, M., S. Labrecque, M. Garneau, and A. Tremblay. Object-based classification of a SPOT-4 image for mapping wetlands in the context of greenhouse gases emissions: The case of the Eastmain region, Quebec, Canada. *Submitted to* : Canadian Journal of Remote Sensing.

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