Diagnosis and Prognosis of Effects of Changes in Lake and Wetland Extent on the Regional Carbon Balance of Northern Eurasia

NASA Land-Cover and Land Use Change (LCLUC)
Science Team Meeting
University of Maryland, College Park, Maryland
January 11-13, 2005

Dennis P. Lettenmaier (University of Washington, Email: dennisl@u.washington.edu)
Kyle C. McDonald (JPL, Email: kyle.c.mcdonald@jpl.nasa.gov)
Laura C. Bowling (University of Purdue, Email: bowling@purdue.edu)
Gianfranco (Frank) De Grandi (EU Joint Research Centre, Ispra, Italy)
Reimer Schnur (Max Planck Institut fuer Meteorologie, Hamburg, Germany)
Nina Speranskaya and Kirill V. Tsytsenko (State Hydrological Institute, Russia)
Damin Kozlov and Yury N. Bochkarev (Moscow State University)
Martin Heimann (Max Planck Institute for Biogeochemistry, Jena, Germany)

Abstract

The Eurasian arctic drainage is a vast area that constitutes over 10 percent of the global land mass. Much of this region is either boreal forest or tundra, both of which are climate-sensitive ecosystems that have undergone some considerable change over the last half-century. The presence of permafrost and modest relief impedes the surface drainage of water and makes lakes and wetlands a prominent feature throughout the region. Most global carbon budgets have concluded that the boreal forest portion of the region is a net sink of as much as 0.5 Pg/year of carbon, while the tundra area is nearly in balance. However, these estimates may be considerably in error, as they account at best approximately for the contribution of methane emissions from wetlands. Methane emissions are sensitive to temperature, which has shown marked increases over the last half-century, and is projected to continue to warm as the global climate changes. Furthermore, while the extent of wetlands within the region may be increasing, most estimates are based on coarse resolution (typically 1 km) satellite data, which lead to substantial underestimates (by factors of two or more) of “minority” land cover classes, like wetlands.

This investigation will address the overarching science question: How have changes in lake and wetland extent in northern Eurasia over the last half-century affected the region’s carbon balance, and how are changes in lakes and wetlands over the region likely to affect its carbon balance over the next century? We will employ high resolution SAR data in combination with in situ data to test and evaluate new lake and wetland, and permafrost models within the Variable Infiltration Capacity (VIC) macroscale hydrology model. The VIC model will be linked with a dynamic terrestrial carbon model, and with a lake and wetland methane model. Evaluation of the carbon and methane models and how they respond to changes in vegetation structure and extent is one of the major challenges of current research. Hence, the focus of this work is to develop methods to reconstruct the time history of terrestrial carbon and methane balances over the arctic, Eurasia, and, using a range of climate scenarios, to interpret how these balances might change over the next century.

1. Introduction

Study Region:

- Eurasia draining to the Arctic Ocean
- 1.5 million km²
- Boreal forest: ~50%, tundra: ~15%
- Wetland extent: ~40% (uncertain)
- Half century, and is projected to continue to warm as the global climate changes. Furthermore, while the extent of wetlands within the region may be increasing, most estimates are based on coarse resolution (typically 1 km) satellite data, which lead to substantial underestimates (by factors of two or more) of “minority” land cover classes, like wetlands.

2. Approach

2.1 Test and Evaluate New VIC Lake and Wetland and Permafrost Dynamics Model

- Use a high resolution SAR data (primarily from JERS) in combination with in situ data provided by Russian colleagues Speranskaya and Tsytsenko at the Russian State Hydrological Institute (St. Petersburg), and Kozlov and Bochkarev at the Moscow State University

2.2 Run New VIC linked with BETHY and a Lake and Wetland Methane Model

- Carried out by MPI collaborators Schnur and Kneib; testing of the carbon and methane models performed with respect to large areas to simulate a high resolution spatial grid and to use a combination of high resolution SAR data, in situ data, and meteorological data as inputs

2.3 Prediction and Reconstruction of Terrestrial Carbon and Methane Balances

- Uses VIC construct, over northern Eurasia domain; use a range of climate scenarios to interpret how these balances might change over the next century

3. Modeling Construct

3.1 Land Surface Hydrology Model: Variable Infiltration Capacity (VIC) Model

- Water and energy balance closure
- Spatially-distributed land cover classification sub-grid variability
- Recent additions for cold land processes

3.2 Methane Model

- Walter and Heimann (2000) with modifications described in Walter et al. (2001a)
- Soil methane production, and transport of methane by diffusion, advection, and through plants modeled explicitly
- Methane production occurs in the anoxic soil: bottom of the soil column to the water table
- Methane production rate controlled by soil temperature and NPP
- Time evolution of soil temperature will come from VIC

4. Observations

4.1 In-Situ Data

- Dynamics of open water surface area, and forest and bog areas collected over Eastern Russia from the 1950s through the 1990s
- Water and vegetation data sets based on inventories performed every 5-10 years: areas at the Russian State Hydrological Institute (SII)
- Quantitative assessments of landscape elements are available for 54 regions with areas from 3000 to 160,000 km²
- Seasonal maps of open water and soil surfaces during the warm months
- Weighing lysimeter data available at 60 sites; pan evaporation observations available at 103 sites; total precipitation data also available

4.2 MODIS

- Levels 1-2 products for MODIS satellite
- Districts of open water, tundra, and forest areas
- Level 2 data from the Satellite Application Facility on Boreal Forests (SAF-BF)

5. Strategy for Constructing Carbon and Methane Balances

5.1 Retrospective Reconstruction of Regional Carbon Balance

- Following model development and testing, lake and wetland extent and associated carbon and methane fluxes will be reconstructed
- Period: 1950 to 2000, using gridded hydrologic forcing data developed at the University of Washington
- Matrix of one degree spatial resolution
- Work with Russian collaborators to assemble additional data over the region that can be used to assess the model predictions

5.2 Century Regional Scenario Analysis

- Ongoing work with improved model simulations for a range of climate scenarios

6. Outline of Tasks

Task 1: Model improvements
- Task 2: CRC Lake and Wetlands model development
- Task 3: Methane model improvements
- Task 4: Integration of VIC in MPI/C/BETHY/LPJ

Task 5: Data preparation and analysis
- Task 6: Model testing and evaluation
- Task 7: Retrospective reconstruction of regional carbon balance
- Task 8: 21st century regional scenario analysis