Modeling Study of Climate-Ecosystem Interaction Over North America

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INTRODUCTION

Climate-ecosystem interaction

- Though soil, topography, and geomorphology influence the distribution of ecosystem, climate is the most important driving force in shaping natural vegetation growth and distribution (Chen et al., 2004).
- Ecosystem feedbacks to atmosphere by affecting water and energy exchanges between. Seasonal and inter-annual climate variability is under strong influence of ecosystem feedback (Wang et al. 2000).

Current Stage of interactive climate – ecosystem study

- Most surface-atmosphere interaction study focused either on atmospheric response to prescribed surface conditions, or vice versa (Zeng et al.,2000).
- Global coupled modeling study has shown that interaction between climate and ecosystem can amplifying or damping the climate changes induced by external forcing (Claussen, 1997).

MODEL DESCRIPTION

Regional Climate modeling System (RCMS)

This study uses a coupled regional climate modeling system (RCMS) that includes interaction between the atmosphere, vegetation, and soil physics. There are three major components in RCMS:

1. Atmospheric component MM5: MM5 is a nonhydrostatic primitive equation model that describes physical and dynamical processes in the atmosphere.
2. Land Surface Transfer Scheme LSX: LSX is a detailed surface model describing the soil, snow, and canopy physical processes (Pollard, 1998).
3. Equilibrium biogeography model BIOME4: BIOME4 functions as a linkage and important interface between soil and atmosphere (Haxeltine et al.). It predicts changes in natural vegetation patterns due to climate changes. In this study BIOME4 is interactively and asynchronously coupled with LSX and MM5.

SCIENTIFIC ISSUES TO ADDRESS

(1) What are the climatic changes caused by doubled CO_{2i}?in North America simulated by high-resolution regional climate model?

(2) How will the ecosystem be reshaped under doubled CO_2 and changed climate in North America?

EXPERIMENT DESIGN

Model Domain

The RCMS domain is centered on (40ºN, -90ºW), covering a region in North America roughly by 4320 x 6480 km^2 with a grid interval of 108 km. The model has 29 levels in the vertical, and model top is 100mb. Prescribed topography is shown in Figure 1.

Large Scale forcing

A 145-year transient archived simulation of Climate System Model (CSM) is used to drive RCMS. In that archived simulation, CSM was run at T42 spectral horizontal resolution with 18 hybrid-sigma levels in the vertical (Boville and Gent, 1998). CSM outputs at year 15-24 (present-day climate) and 95-104 (future scenario under doubled CO_2) are used to provide boundary conditions for RCMS.

Experiments

Two RCMS simulations have been performed in this study, each 10 years in length: 1) a present-day control run with potential vegetation specified by BIOME4 driven by present observed climatology; 2) a doubled CO_2 run with interactive BIOME4, which updated vegetation distribution and related physical parameters at yearly basis.

Model evaluation

Climate Change Research Unit (CRU) 1961-1990 observed climatology (New et al., 1999) is used to evaluate RCMS performance in surface temperature and precipitation simulation for present-day climate.

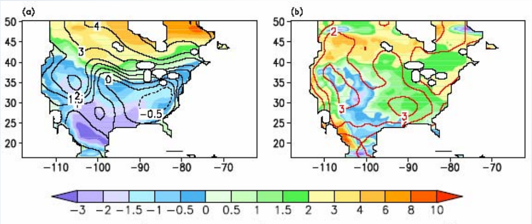

Figure 1. Changes (doubled CO2 minus present) in monthly mean surface temperature (°C) simulated by MM5 (shaded) and CSM (contour). (a) January. (b) July

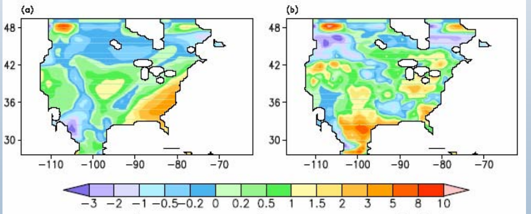

Figure 2. Changes (doubled CO2 minus present) in monthly mean precipitation (mm/day) for (a) January and (b) July.

RESULTS

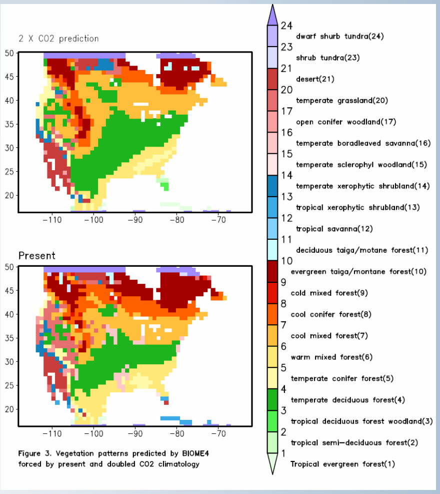

Figure 3. Vegetation patterns predicted by BIOME4 forced by present and doubled CO2 climatology

1. Doubled CO2 conditions induced strong high-latitude warming, while the southern U.S. became cooler in winter (Figure 1).
2. Across almost all of the model domain precipitation tended to increase in all seasons with the highest intensification found over the Northeast, Southeast, and the Great Plains (Figure 2).
3. In response to this future climate scenario, vegetation migrated northward systematically in the eastern United States. In particular, the sparsely vegetated area around Hudson Bay was predicted to be covered by cool conifer forests in the future warming climate. Over the Great Plains and part of the Midwest, water supply is the crucial factor that affects natural vegetation evolution, and more precipitation under doubled CO2 led to temperate deciduous forests extending toward north and northwest. Grasslands in the northern half of the Great Plains will be replaced by cool conifer and mixed forests due to more precipitation in the future (Figure 3).

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