II. MODELING PRE-INDUSTRIAL C-N-P-S BIOGEOCHEMICAL CYCLING IN THE LAND-COASTAL MARGIN SYSTEM

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ABSTRACT

Human activities were important forcing functions in the pre-industrial world and have become increasingly more important in the 21st century. Because of both natural temperature changes and pre-industrial anthropogenic activities, the carbon and nitrogen cycles were not in steady state prior to the Industrial Revolution and the beginning of important fossil fuel emissions to the atmosphere. In order to examine the role of the land-coastal margin system in global climate forcing and to assess changes in element cycling in response to natural and anthropogenic forcings, we have developed a conceptual model for the C-N-P-S biogeochemical cycles in this critical ecological zone. To demonstrate the application of the model, we evaluate the behavior of the coupled C-

N-P cycles in the land-coastal margin system in response to a sustained global temperature perturbation on terrestrial denitrification.

Model results show that the nutrient-limited coastal margin is extremely sensitive to changes in the dissolved and particulate organic matter loading from land via the rivers. These results suggest that perturbations affecting the terrestrial denitrification flux are amplified rather than attenuated in the coastal margin. In a global warming scenario with enhanced terrestrial denitrification, the coastal margin becomes more autotrophic relative to its present heterotrophic status. In contrast, in the case of a cooling scenario with decreased denitrification fluxes on land, the coastal margin becomes more heterotrophic relative to its initial status. For the +10 ° to –10 °C range of temperature perturbations simulated by our model, net ecosystem metabolism of the coastal margin varied by a factor of 34, from about $+0.5 \times 10^{12}$ to -17×10^{12} moles of carbon per year. It is evident that the coastal margin trophic status is principally governed by changes in the flux of organic matter from land. The effect of changes in the riverine flux of inorganic nutrients to the coastal ocean, which changes in the same direction as that of the riverine organic flux, is small compared to that of terrestrial organic matter loading.

We argue that the effects of temperature change and of certain land-use activities, such as deforestation, are similar with respect to the nitrogen cycle in the coupled land-coastal margin system. Natural global temperature variations over the last 6000 years of Earth's history, including the relative warmth of the Holocene Climatic Optimum and the Medieval Warm Period and the coolness of the Little Ice Age, probably led to changes in denitrification fluxes on land and transport of organic matter and inorganic nutrients to the coastal oceans by rivers and groundwater. Pre-industrial anthropogenic activities on land probably enhanced the delivery of organic and inorganic nitrogen and organic matter to the oceans. These variations in the riverine flux led to continuous change in the trophic status of the global coastal margin and in the air-sea exchange of CO_2.

The global analysis provides some insight into the direction of change but does not provide quantitative estimates of the magnitude of change. However, there is little doubt that on a global scale, downstream reservoirs of shallow groundwater, rivers and coastal margins can be affected relatively rapidly by changes in terrestrial denitrification fluxes brought about by natural temperature variations and land-use activities. The land-coastal margin system must be viewed as an entity in considerations of global environmental change.

IIA. INTRODUCTION

Human activities have become important forcing functions in biogeochemical cycling on land and in coastal margins through a number of processes operating on different time scales. Because of the potential of an enhanced greenhouse effect and consequent global climatic change, much research effort in recent years has focused on the global carbon cycle. In order to assess fully the behavior of the reservoirs in the exogenic Earth system in response to natural and anthropogenic forcings, it is necessary to study the biogeochemical cycling of the elements carbon, nitrogen, phosphorus and