Parallel computing of forest biotic dynamics

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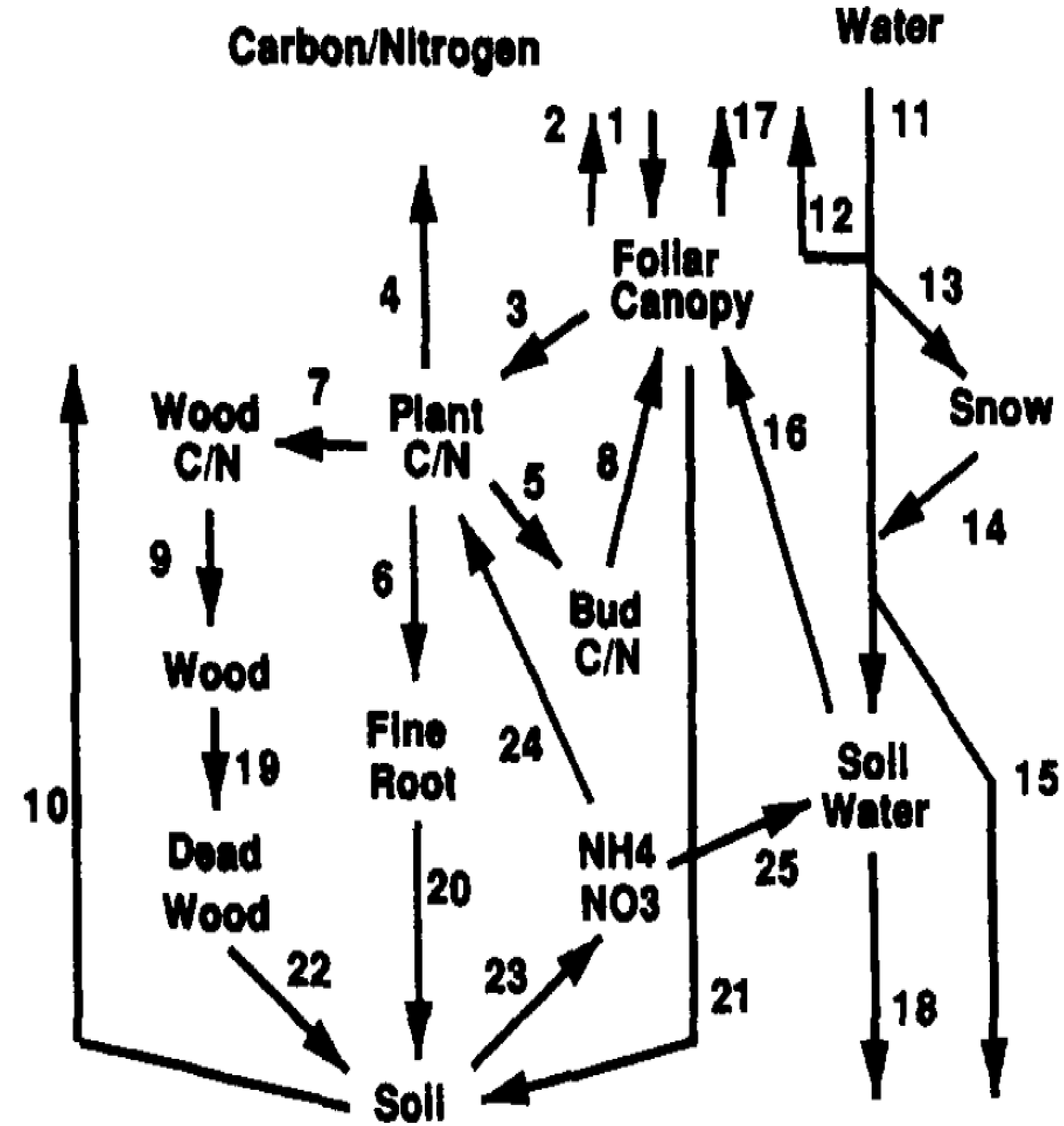
Abstract: This poster presents a parallel-computing framework developed recently through the collaborative efforts between the College of Food, Agriculture and Natural Resources Sciences, The Institute of the Environment, and the Supercomputing Institute at the University of Minnesota. The goal of this project is to address the challenges encountered in the modeling of biotic dynamics in a forest region across different time and spatial scales. By implementing the parallel computing framework on Itasca, we have been able to reduce the computing time from 46 days (if the simulation runs on a single desktop) to a half day by using 8 nodes for a study region of northern Minnesota, Wisconsin, and Michigan with 1 km grid resolution. This will allow us to attack computationally challenging problems, such as assessing the impact of critical events like the 1999 BWCA blowdown and finer resolution events such as controlled burns on future forest productivity and stability.

Introduction

We are using PnET-CN for modeling the effects of disturbances, such as climate change drivers, fire, and harvest scenarios, on plant biotic processes, such as productivity, photosynthesis, respiration, and transpiration. We use abiotic environmental templates (such as temperature, moisture, and solar radiation gradients). These effects occur heterogeneously across temporal and spatial scales. For example, thousands of spatial grids are essential to cover a region of interest (e.g., ecoprovince 212 in northcentral North America). The number of calculations required to run the model on individual grids would impractical on a single multi-core computer.

PnET-CN structure

A Matlab package which provides a modular approach to simulating the carbon, water and nitrogen dynamics of forest ecosystems.



Aber et al. 1997 Ecological Modelling

1. Gross Photosynthesis
2. Foliar Respiration
3. Transfer to Mobile C
4. Growth and Maint. Resp.
5. Allocation to Buds
6. Allocation to Fine Roots
7. Allocation to Wood
8.Foliar Production
9. Wood Production
10. Soil Respiration
11. Precipitation
12. Interception
13. Snow-Rain Partition
14. Snowmelt
15. Fast Flow
16. Water Uptake
17. Transpiration
18. Drainage
19. Wood Litter
20. Root Litter
21. Foliar Litter
22. Wood Decay
23. Mineralization
24. N Uptake
25. To Soil Solution

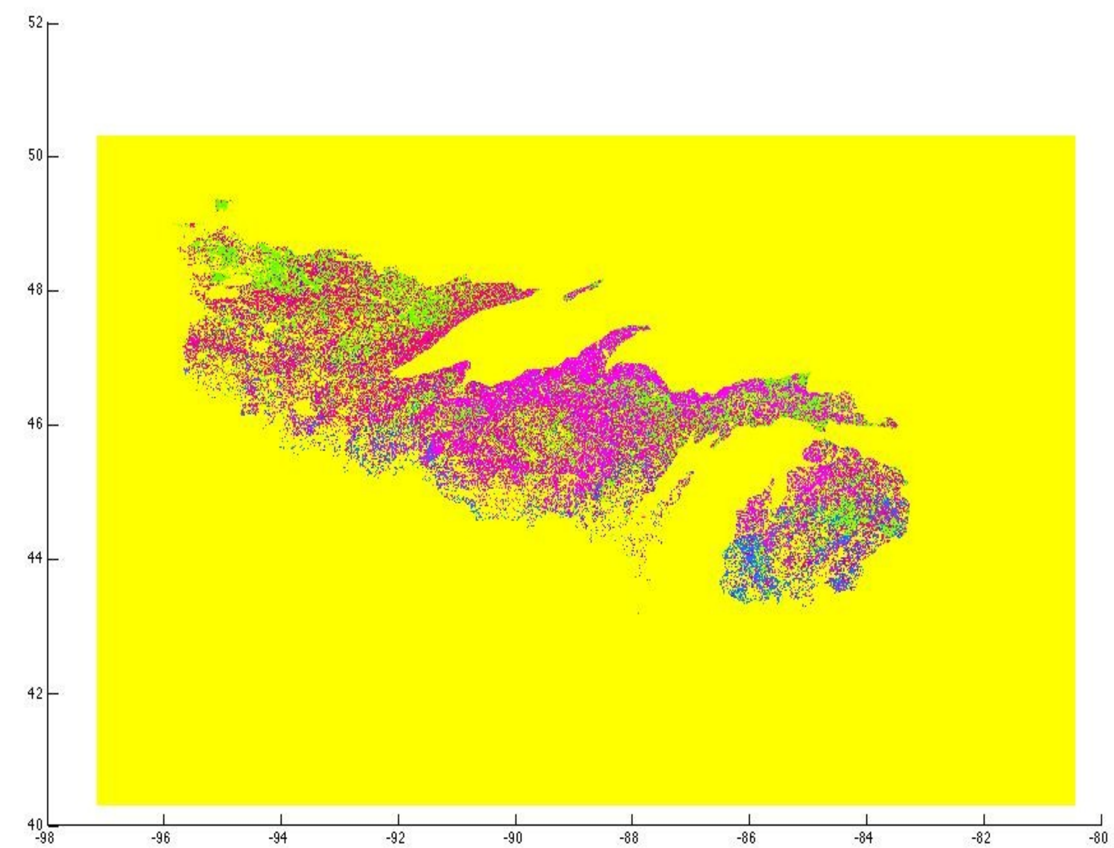
PnET-CN Inputs

Climate and atmospheric inputs
-Mean monthly Tmin
-Mean monthly Tmax
-Cumulative monthly precipitation
-Mean monthly instantaneous PAR
-CO_2 concentration
-N deposition rates
-O_3 concentration (D40)

Vegetation Parameters (n=46)
-Canopy traits (k, leaf lifespan, SL
-Photosynthesis / respiration
-Water balance
-Carbon allocation
-Biomass turnover
-N concentration

Site Parameters
-Soil water holding capacity
-Latitude

Disturbances (optional)
-Mortality
-Land use history
biomass removal / harvest
Fire wind throw



NW212 forest type grid

1. Aspen – birch
2. Pine
3. Spruce – fir
4. Oak – hickory
5. Elm – ash – cottenwood
6. Maple – beach – birch

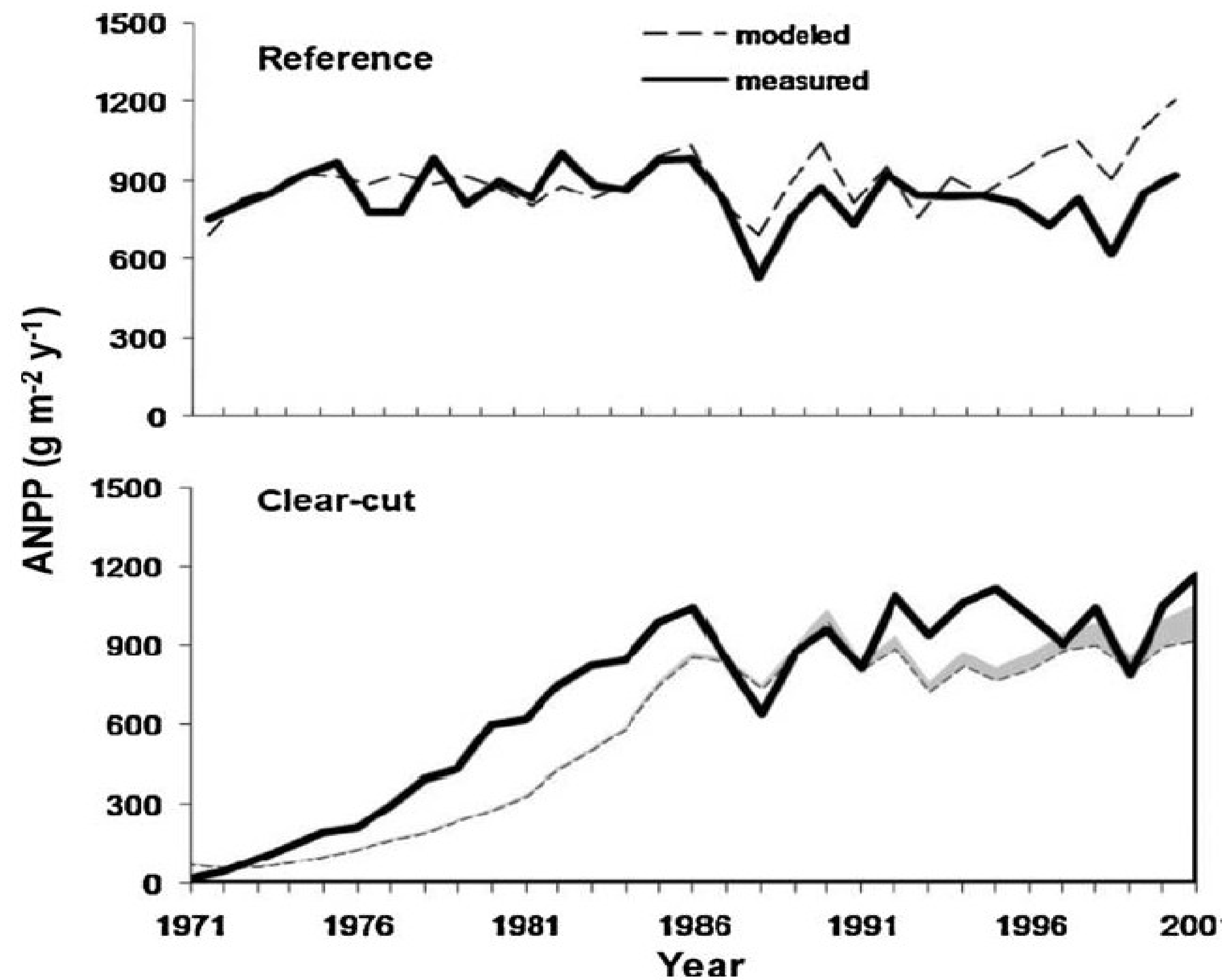
PnET-CN Outputs

Deciduous hardwood forest Parsons, WV

C cycling
-Net primary production
(wood, foliage, roots)
-Net ecosystem production
-C storage (wood, foliage, roots)

N cycling
-Net N mineralization
-Net nitrification
-Foliar N concentration
-N leaching

H_2O cycling
-Evapotranspiration rates
-Drainage / runoff



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Massively parallel computing framework

A FORTRAN interface named as Ppnet has been developed, which uses MPI for simulating the carbon, water and nitrogen dynamics of forest ecosystems over many grids in parallel. Ppnet adopts a flexible algorithm that maps the coordinates of the forestry grids to any number of computer cores. The feature is necessary in a multi-user dynamic computing environment, so that the parallel run can start with the available computing cores, which is not predictable in a muli-user environment, like the Supercomputing Institute.

The IO Management

Great I/O change appears when the parallel calculation over millions grids covering the forest region is in production as each of the grids needs individual input and produces a set of outputs. Also some grids may fail due to some missing or incomplete data. A tool of IO management was developed, which dynamically loads the inputs of millions of files onto /scratch. For the outputs, data is stored on local/scratch temporarily. As the simulation proceeds, these finished grids are moved to the specified location. This tool also reports diagnosis if any failures occur at some grids.

Discussion and Conclusion

A massively parallel-computing framework has been developed with linear scaling capability. We have been able to reduce the computing time from 46 days (if the simulation runs on a single desktop) to a half day by using 8 nodes on Itasca for a study region of north America with 1 km grid resolution. Further development is in the plan for enabling the communications across grids and post processing.

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