

# **Parameterization and Sensitivity Analysis of a Complex Computer Simulation**

Kyle Roskoski

UROP Final Report

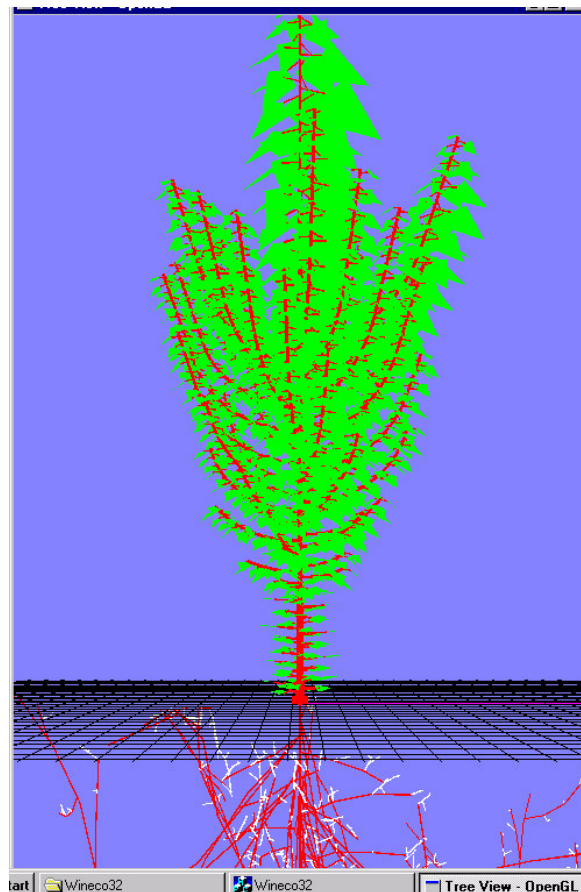
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Faculty Sponsor: Dr. Kathryn Lenz, Department of Mathematics and Statistics

Co-Sponsor: Dr. George Host, Natural Resources Research Institute

## 1. Introduction

ECOPHYS is a complex computer model that simulates the growth of poplar and aspen trees. The primary purposes of the ECOPHYS model are to identify major physiologically based factors that influence the growth of trees and to predict how interactions among them will affect growth (Host et al., 1990). ECOPHYS uses a variety of weather and clonal inputs. A sample screen shot of an ECOPHYS simulation in the second year is shown in Figure 1.



**Figure 1**

There are many parameters within ECOPHYS that need to be determined in order for ECOPHYS to simulate tree growth. I determined what some of the parameter values

should be for aspen clone 259 based on field measurement data received from the Free-Air CO<sub>2</sub> and O<sub>3</sub> Enrichment (FACE) site in Rhinelander Wisconsin (<http://www.nrri.umn.edu/factsii>). Other tasks I dealt with were leaf initiation rate, trunk and branch diameter discrepancies, model verification and some analysis of the sensitivity of ECOPHYS growth to weather patterns.

The FACE site was established in 1997 in order for researchers to study the growth of five different aspen clones, as well as maple and birch trees in the presence of elevated levels of carbon dioxide (CO<sub>2</sub>) and elevated ozone (O<sub>3</sub>) gases. The main objective of the experiment is to examine, for predictive purposes, the effects of elevated CO<sub>2</sub> and O<sub>3</sub> on ecological interactions of northern hardwood forests (Dickson et al., 2000). There are twelve rings at the site containing 584 trees. Three of the rings are treated with elevated CO<sub>2</sub>, three are treated with elevated O<sub>3</sub>, three are treated with both elevated CO<sub>2</sub> and O<sub>3</sub>, and three do not have elevated CO<sub>2</sub> or elevated O<sub>3</sub>. The last three rings are referred to as the control rings. We have received weather data from the FACE site, including temperature, light intensity, relative humidity, CO<sub>2</sub> and O<sub>3</sub> for 1998, 1999, and 2000. We have also received phenological and growth data from the FACE site. The phenological data includes bud-break, bud-set and end-of-season leaf drop dates for 1999 and 2000. The growth data includes stem height and stem diameter for 1998 and 2000, and leaf area for 2000. We also have stem height and stem diameter modified averages for 1999 (Isebrands et al., 2002). I have organized the data that we have received so far from the FACE site based on aspen clone and then on treatment. Right now we are focusing on the clone Aspen 259, but other clones will be investigated in the future.

## 2. Tasks and Results

For my project I investigated various parameters that need to be set in ECOPHYS. Some of these parameters are the bud-break date, leaf initiation rate, bud-set date, end-of-season leaf drop start date, and end-of-season leaf drop rate. The bud-break date is the date that the buds break on a tree and new leaves emerge in the beginning of a growing season. The leaf initiation rate determines the number of hours there are between emergences of consecutive new leaves on a branch. The bud-set date determines when a tree sets its buds at the end of a growing season and stops producing new leaves. End-of-season leaf drop refers to when a trees leaves change color and drop in the fall.

I have found reasonable bud-break, bud-set, and end-of-season leaf drop dates for 1999 (Roskoski, In Progress). I'm still investigating what these parameters should be in other years. There are other factors that need to be looked at before I can determine what some of these dates should be, such as pest and virus interactions.

Another task that I did, not originally planned in my proposal, was to observe the diameter of the simulated tree to see if it tapers as expected after a one-year run of ECOPHYS. An internode is a section of the stem or trunk between two consecutive leaves. The internode diameters of the trunk should gradually decrease from the base of the trunk to the top of the tree.

After running some tests, I observed that ECOPHYS did not do this and had two problems with its first year tree. The first problem I identified, concerned the initial four internodes. These internodes weren't getting as thick as the subsequent internodes. ECOPHYS starts with an initial whirl of four leaves attached to four internodes. I found that the cause of the first problem was that the first four internodes were initialized to one

centimeter long while each of the new internodes thereafter were initialized to one half centimeter. To fix this problem I changed the first four internodes to one half centimeter. This resulted in thicker diameter for the first four internodes (Roskoski, In Progress).

The second problem identified concerning internode diameters occurred when a leaf dropped during the growing season. The internode that the leaf was on did not continue to receive photosynthate. Therefore, it didn't continue to increase in diameter while the surrounding internodes continued to thicken. We determined that this was caused by a problem in ECOPHYS's carbon transport sub-model. This sub-model has since been replaced (Guan, In Progress). I will repeat my analysis of internode diameters this summer with the new carbon transport sub-model in place.

A third problem with internode diameters identified during my investigation was that the trunk of a two-year simulated tree did not increase much beyond that of its first growing season. I will check the new carbon transport sub-model and find out if the problem has been fixed.

### **3. Trip to Rhinelander, WI**

The ECOPHYS group: Dr. Kathryn Lenz and Dr. Harlan Stech from the Department of Mathematics and Statistics; Dr. George Host, Senior Research Scientist at NRRI and Co-Sponsor; graduate students, Larry Tordsen and Yongtao Guan; and undergraduate student, Mariah Olson took a trip to the FACE site in April 2002. While we were there, we met with four of the FACE experiment plant physiologists, Jud Isebrands, Mark Kubiske, Evan McDonald, and Bill Mattson. We had a five-hour meeting discussing things going on at the FACE site as well as discussing the various

aspects of ECOPHYS. During this meeting, I gave a short presentation about the data that we had received so far from the FACE site, and how I'd been using it to parameterize ECOPHYS. I also gave a brief explanation about the UROP program. The FACE investigators gave us some new ideas for ECOPHYS, and answered questions that we had about the data. They also answered complex questions about how the trees grow and some difficulties of modeling tree growth. After the meeting, Dr. Kubiske, who is also the FACE site coordinator, brought us over to the FACE site and showed us around. He brought us into some of the rings, pointed out different aspects of the site, and let us take some measurements.

In May 2002, Jud Isebrands met with us at UMD to further discuss carbon distribution within a tree. He explained in more detail how a tree distributes its photosynthate for growth and discussed some ideas about how to model this distribution.

#### **4. Future Work**

I am continuing my research work on ECOPHYS this summer and fall. Some of my future work involves varying the growing-season leaf drop parameters, participating in developing a new model for carbon distribution, varying the leaf initiation rate, and additional work with bud-set, end-of-season leaf drop, and other phenological and growth data from the Rhinelander FACE site.

My analysis so far suggests that both ECOPHYS's leaf initiation rate and ECOPHYS's leaf drop parameters may need to be adjusted. Data was not collected at the FACE site concerning these parameters. Therefore, I will get field data estimates on how

many leaves drop over the course of a growing season when I return to Rhinelander this July.

I will be returning to the Rhinelander FACE site again this summer for one week to help with the biomass harvest in July. The harvest involves digging up four trees from each ring to obtain measurements of coarse roots, fine roots, stems and leaves. While in Rhinelander, I will look more closely at the trees and collect data on how many leaves have dropped and how many internodes there are on a branch. At that date, I will also be looking at leaf area, specific gravity for internodes, and internode diameters and lengths. Using the data that I collect at the FACE site, I will vary the leaf drop parameters in ECOPHYS to study the effects of mid-season leaf drop on simulated growth. While we were hoping to receive some data previously collected at the FACE site to help with this, there was no data acquired for in-season leaf drop or leaf initiation rate.

The current model for ECOPHYS's carbon distribution has a few problems. When in Rhinelander last April and again when Dr. Isebrands visited us, there was discussion about a new idea for carbon distribution in ECOPHYS. Part of my future work involves participating in developing a new model for carbon distribution throughout the tree canopy and root system.

I will also be doing additional work with bud-set and senescence rates to observe if CO<sub>2</sub> and O<sub>3</sub> have an effect on when bud-set and senescence occur. I will look at the correlation of elevated CO<sub>2</sub> and delayed bud-set and also the correlation of elevated O<sub>3</sub> and early bud-set.

## **5. Evaluation**

I feel that I have accomplished the educational objectives that I proposed, and some objectives that I didn't propose as well. My advisor, Dr. Kathryn Lenz, has been very knowledgeable and helpful throughout my research. I met with Dr. Lenz twice weekly to discuss ideas and for help on any issue that occurred throughout my UROP. Dr. Lenz has also taught me plenty about writing technical papers.

My UROP experience was a great benefit to my education. It allowed me to further explore what one does in research, something that was hard for me to understand until experiencing it first hand. I've benefited greatly from working with a very knowledgeable faculty. Dr. Lenz, Dr. Host, and Dr. Stech have been extremely helpful and have provided a lot of feedback throughout my research. The ECOPHYS group met at weekly meetings where we discussed progress, answered questions, and provided ideas for other group members. From these meetings, I have learned about the importance of communication among group members when working on a project together. I have also learned about the importance of accomplishing certain tasks on time in order for others to complete theirs.

The only complaint that I had with the UROP program was that there was no notice that expense money should be requested for a poster in the poster presentation. I would think that the Visualization and Digital Imaging Lab (VDIL) at UMD would allow UROP students to produce posters for their research presentations. The VDIL would not print out posters or allow me to print my poster for the UROP poster presentation. I had to pay to print out my poster at print services. This cost just under \$100.

Overall, I learned a lot by completing a UROP project. It was a rewarding experience and a valuable part of my education. I'd highly recommend it to others.

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