

8.6 COMPARISON OF SIMULATED STEM TEMPERATURES AND OBSERVED AIR TEMPERATURES WITH OBSERVED STEM GROWTH IN FOREST OPENINGS

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1. INTRODUCTION

Phenology, the study of how plant or animal developmental stages relate to the organism's surrounding climate, is a well established discipline with roots dating back more than 2000 years (Hopp and Blair, 1973). For example, correlations are often noted between budbreak or first blossom and integrated air temperature (commonly referred to as heat sums.) The underlying assumption in seeking these correlations is that biological processes proceed at rates proportional to temperature.

Depending on the organism under consideration, either air, soil, or water temperatures may serve as the basis for computing heat sums. For trees, shrubs and agricultural crops, the most common basis is air temperature. Not only is air temperature representative of the plant's environment, but air temperature is more easily measured than soil temperature and extensive air temperature records are readily available.

However, the biological processes involved in plant growth do not occur in open air; they occur within the plant tissue. There can be substantial differences between local air temperatures and plant tissue temperatures due to insolation or infrared radiative fluxes (e.g., Harvey 1923; Sakai 1966).

Caprio (1971) proposed the inclusion of solar radiation in the computation of heat sums. He presented a mathematical model that used the product of insolation and temperature where earlier models had used just temperature. Later, Caprio and Snyder (1991) compared a variety of thermal and solar-thermal models with data on the flowering of *Syringa vulgaris* L., the common purple lilac. Both of their solar-thermal models were multiplicative.

Recently, Potter and Andresen (2002) presented a numerical model for temperatures and heat flow within tree stems. The model uses the differential equations for heat transfer,

with observed air temperature, winds and insolation to determine temperatures within a tree stem and how they vary in time.

In the present study, we use the Potter and Andresen (2002) model in conjunction with observed meteorological and plant growth data from a canopy gap study in northern Wisconsin to compare air-based heat sums and stem-based heat sums, and how these two correlate with plant growth.

2. METHODS

The observational data for the atmosphere and vegetation came from an ongoing study of the role of canopy gaps on processes in northern hardwood ecosystems (Strong, et al. 1998.) The gap used for the present study had a diameter-to-height ratio of 2, with actual diameter of 150 feet (46 m). Air temperature was measured and recorded hourly at gap center, as well as halfway to the edges and at the edges along the cardinal axes. Photosynthetically active radiation (PAR, 400-700 nm) and winds were measured at gap center and also recorded hourly. Because PAR is only part of the solar spectrum, we multiplied observed values by 1.55, roughly the ratio of total solar flux to solar flux between 400 and 700 nm. All meteorological observations were made at 1 m above ground.

Vegetation data came from the same gap study. Seedling growth from 1997 through 2000 was measured on all seedlings at the same sites as the meteorological data. Growth for *Acer saccharum* Marsh. (sugar maple) and *Fraxinus americana* L. (white ash) was recorded specifically, and growth of all tree seedlings in the vegetation plots was recorded collectively as well. In addition, percent of each plot covered by *rubus* spp. was recorded.

There are equations for calculating the theoretical direct and diffuse solar flux on a horizontal surface. However, some points in a gap receive direct sunlight at times others do not. A forest is not entirely opaque and some light will pass through it before the sun rises

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above the gap "rim." And finally, cloud cover varies in time and alters the solar flux at the ground.

To address these concerns, we first used a C++ program to compute hourly theoretical fluxes at the observation locations in the gap, taking into account the gap geometry. We assumed a semitransparent forest with an extinction coefficient of 0.015 m^{-1} , based on best-fit calculations with the observed data at gap center. Finally, we multiplied these theoretical hourly values at the off-center points by the ratio of observed to theoretical flux at gap center to reflect the cloud conditions.

We configured the Potter and Andresen (2002) model to simulate a 2 cm diameter stem. Values for wood density, moisture content, and thermal diffusivity were estimated based on Ten Wolde et al. (1988) and Forest Products Laboratory (1987).

3. RESULTS

Correlations between observed seedling growth and air temperatures are negative for *Fraxinus* ($r = -0.39$) and all species combined ($r = -0.16$). *Acer* had a weak positive correlation between growth and air temperature ($r = 0.18$). Throughout the gap, *rubus* covers roughly 60% of the area and significantly alters the energy balance in the lowest 1 to 2 m. But *rubus*, too, shows a negative correlation with air temperatures ($r = -0.12$).

At the time of this writing, the stem temperature simulations are not complete. Preliminary results show significant nonlinear variations in growth of *Acer* and *Fraxinus* along a north-south transect.

4. CONCLUSIONS

The results of correlations between vegetation growth and stem temperatures will be presented at the conference. Initial results suggest that the stem temperatures are similar to the air temperatures, and that wind and clouds reduce the within-gap temperature variations one would expect to see with clear skies and no wind. The dense *rubus* coverage also complicates the interpretation of gradients and correlations in the observational data.

Sunlight's photosynthetic importance confounds any attempt to evaluate the effects of solar heating on plant growth. There will always be a dual effect of sunlight on plants, through warming and photosynthesis. In our study, we

could not untangle this coupling and the question remains of whether any correlation between growth and stem temperature is truly a temperature effect, or an indirect reflection of photosynthesis. Separation of these two effects will likely require a controlled laboratory environment.

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