Simon Thomas - Burns Fund Summer Fellowship

Over eight weeks this summer I worked with Professor Mark Battle in the Department of Physics and Astronomy. For years, Professor Battle has taken measurements of oxygen and carbon dioxide on a measurement tower in Harvard Forest, located in central Massachusetts. Using these measurements, Professor Battle has published research on the 'exchange ratio' of oxygen and carbon dioxide. This ratio provides useful insight into the amount of carbon sequestered and stored by the terrestrial biosphere.

Recent research conducted in Hyytiälä, Finland utilized a different measurement technique to measure the flows of oxygen and carbon dioxide into and out of a boreal forest. This technique, called the flux-gradient method, may allow for improved measurement of gas flows in the air above forests. In the coming year, Harvard Forest plans to remove the measurement tower and install a taller replacement. My primary research task was determining the feasibility of making flux-gradient oxygen measurements with the future tower.

Oxygen makes up more than 20 percent of the atmosphere; as a result, it is difficult to measure the small changes in oxygen concentration caused by plants photosynthesizing. My summer work began with research into previous oxygen/carbon dioxide studies and investigation of various micrometeorological measurement techniques. After corresponding with authors of the recent research in Finland, I began to develop a numerical model to simulate the diffusion of gasses above a forest canopy. This model simulated the bottom kilometer of the atmosphere, allowing us to predict concentrations of oxygen at different heights above the forest. To make the model as accurate as possible, we used data from previous research at Harvard Forest on the atmospheric conditions in the area and forest oxygen production. After several changes to the model to ensure that the physical laws were being simulated correctly, we ran ten-day simulations and analyzed the results.

Flux-gradient calculations require a measurable difference in oxygen concentration between two different heights. Given the precision of our oxygen measurement apparatus, a minimum concentration difference of about one part per million would be required between the two heights. Our model suggests that the proposed tower would be able to measure a difference of about 0.6 parts per million on a typical summer day — not enough to reliably make flux gradient measurements. While our model includes many approximations and is certainly not a perfect representation of the atmosphere, it does suggest that either a taller tower or more precise equipment would be necessary to have high confidence in the feasibility of flux-gradient measurements. The simulations showed that it is very likely, however, that carbon dioxide flux-gradient measurements can be made from the future tower. To assess the model's reliability, multiple simulations were run with various changes to model parameters. These runs supported the model's validity, showing that the parameters chosen during development had relatively small effects on the results. I expect that future research on this project will be conducted with data from the new tower, as researchers will be able to draw comparisons between carbon dioxide measurements collected at the same location with different techniques.