Final Scientific/Technical Report

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Title: Improving models to predict phenological responses to global change

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Distribution Limitation Notice

All data from this project are publicly available, in near real time, through a project web page. There are no limits on the distribution of this report.

Executive Summary

The term *phenology* describes both the seasonal rhythms of plants and animals, and the study of these rhythms. Plant phenological processes, including, for example, when leaves emerge in the spring and change color in the autumn, are highly responsive to variation in weather (e.g. a warm vs. cold spring) as well as longer-term changes in climate (e.g. warming trends and changes in the timing and amount of rainfall).

We conducted a study to investigate the phenological response of northern peatland communities to global change. Field work was conducted at the SPRUCE experiment in northern Minnesota, where we installed 10 digital cameras. Imagery from the cameras is being used to track shifts in plant phenology driven by elevated carbon dioxide and elevated temperature in the different SPRUCE experimental treatments. Camera imagery and derived products ("greenness") is being posted in near-real time on a publicly available web page (http://phenocam.sr.unh.edu/webcam/gallery/). The images will provide a permanent visual record of the progression of the experiment over the next 10 years.

Integrated with other measurements collected as part of the SPRUCE program, this study is providing insight into the degree to which phenology may mediate future shifts in carbon uptake and storage by peatland ecosystems. In the future, these data will be used to develop improved models of vegetation phenology, which will be tested against ground observations collected by a local collaborator.

Project Activities

Objectives and Tasks

The over-arching objective of the proposed work is to improve understanding of the complex drivers and mechanisms that control phenology at organism-to-ecosystem scales. Specific tasks of this project were to:

1) use networked digital cameras to monitor vegetation phenology at a multi-factor global change experiment (the SPRUCE experiment in northern Minnesota);
2) use data derived from the camera imagery, in conjunction with long-term ground observations, to develop and test models of species-level and community-level phenology; and
3) use the validated models to forecast phenological responses of peatland ecosystems under future temperature and atmospheric CO_2 scenarios.

Our progress towards each of these tasks is described below.

Task 1: Installation and maintenance of PhenoCams at the SPRUCE Experiment

Following deployment of a test camera (Figure 1) at SPRUCE in October, 2014, we returned to the site in August 2015, after construction of the 10 experimental chambers was complete and electrical power and internet connections were installed.

We installed one StarDot NetCam SC IR camera in each chamber, on the south wall at a height of approximately 6 m and angled downward so that the entire area enclosed by the boardwalk within each chamber is clearly visible (see sample image, from Chamber 11, in Figure 1).

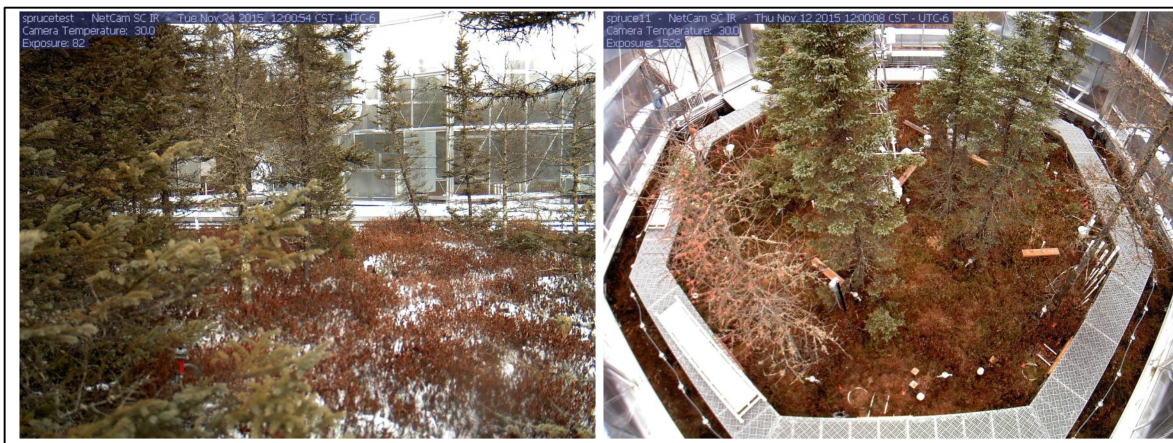

Figure 1. Left, image from the test camera, which is located outside of the experimental chambers. Right, image from the camera inside Chamber 11 (elevated CO2, +2.25°C).

Every 30 minutes, two pictures (a Red, Green, Blue image at visible wavelengths; and a monochrome image that includes both visible and near-infrared wavelengths) are recorded and sent over the Internet, via FTP, to the PhenoCam server at the University of New Hampshire.

Within 30 minutes, the latest image from each chamber is displayed on the PhenoCam (http://phenocam.sr.unh.edu/) "site page" (see Figure 2, below). The images are all publicly available, and can be viewed by anyone, anywhere (from Grand Rapids to Oak Ridge, and from Washington to Beijing) in the world. Every night the images are analyzed for their "greenness", which is an index that we are using to track the vegetation phenology within each chamber. Graphs depicting the seasonal trajectory for greenness are updated at the same time and are posted on each chamber's site page (Figure 2).

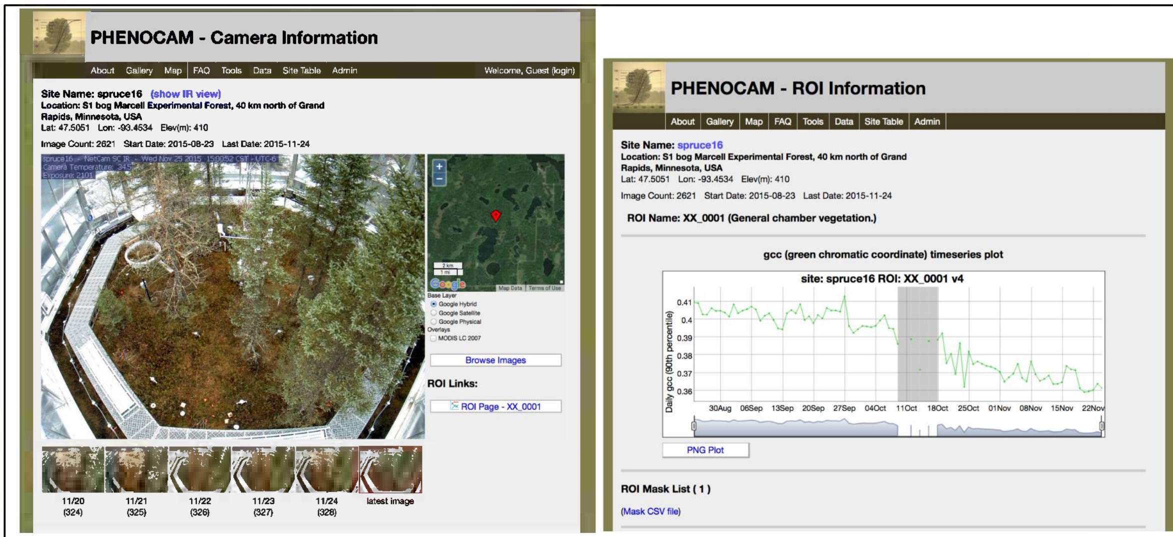

Figure 2. Screenshots from the PhenoCam project web page. Left: "site" page for chamber 11, showing the most recent image, plus images from the last 5 days. Right: the "ROI" page, showing a plot of canopy greenness, derived from image analysis of a specific ROI (region-of-interest) within each picture (in this case, the area enclosed by the octagonal boardwalk).

With only 3 months of data, it is difficult to see strong seasonal patterns, or differences among experimental treatments. However, data from the test camera show that both the evergreen spruce trees, and the shrub layer, exhibit surprisingly strong seasonal cycles of greenness (Figure 3), and preliminary analysis of data from the experimental chambers suggests that the warmest (+9°C) chambers have higher levels of greenness later in the autumn than the ambient temperature chambers (Figure 3).

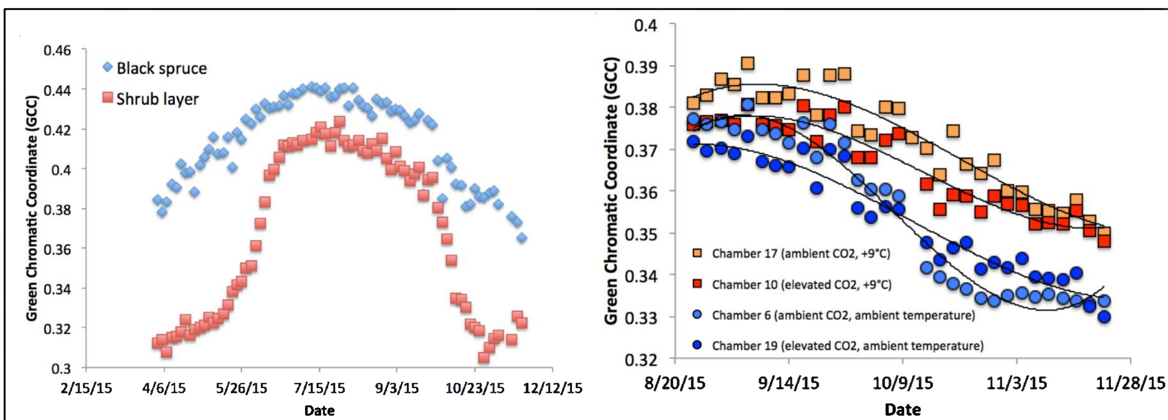

Figure 3. Greenness time series derived from SPRUCE camera imagery. Left: seasonality of vegetation greenness differs between black spruce (higher overall greenness, lower seasonal amplitude, longer duration greenness) and the shrub layer. Right: Experimentally warmed chambers appear to have higher overall greenness, and later autumn decrease in greenness, compared to ambient temperature chambers.

In addition to enabling the tracking of how vegetation phenology responds to elevated temperature and CO2 treatments, these photographs will also provide a unique visual record of the 10-year course of the experiment.

Task 2: Development of improved phenological models

Already, we have preliminary evidence for are differences among experimental treatments in the community-level phenology (i.e., averaging across the vegetation enclosed by the octagonal boardwalk) within each chamber. These patterns are illustrated in Figure 3, above.

Because of unanticipated delays (beyond the control of the PI of this award) in getting the SPRUCE infrastructure built and the experimental treatments operational, modeling using the new data provided by these cameras could not be completed within the project's period of performance. After a full year of data has been obtained from the cameras, we will begin to investigate more comprehensively whether there are differences among experimental treatments that can inform model parameterization and model selection analyses.

As part of Task 2, we initially proposed that our phenological models would be validated against ground observations collected over the last 3 decades by a local collaborator, John Latimer. We have worked closely with John over the last 12 months to clean up and perform quality control on his datasets. Preliminary analyses of these data were presented in a poster (by PhD student Miriam Johnston) at the DOE PI meeting in Potomac, MD in May 2015. Unfortunately, there is minimal overlap between the species in the Latimer dataset, and the species within the experimental chambers, which will limit the potential for us to use these data for model evaluation.

Task 3: Forward model runs

Our plan to forecast phenological responses of peatland ecosystems under future temperature and atmospheric CO_2 scenarios could not be completed during the project's period of performance, but will be the target of future efforts once we have sufficient data to complete Task 2.

Products developed under the award

a. Publications: none.
b. Web sites: Camera imagery is posted in near-real-time to the web pages listed below. Data products ("canopy greenness") derived from the imagery can be viewed online by clicking the "ROI links" button on each camera page:

Chamber	**Temp. (°C)**	**CO_2**	**Camera link**
4	+4.5	elevated	http://phenocam.sr.unh.edu/webcam/sites/spruce4/
6	+0	ambient	http://phenocam.sr.unh.edu/webcam/sites/spruce6/
8	+6.75	ambient	http://phenocam.sr.unh.edu/webcam/sites/spruce8/
10	+9	elevated	http://phenocam.sr.unh.edu/webcam/sites/spruce10/
11	+2.25	elevated	http://phenocam.sr.unh.edu/webcam/sites/spruce11/
13	+4.5	ambient	http://phenocam.sr.unh.edu/webcam/sites/spruce13/
16	+6.75	elevated	http://phenocam.sr.unh.edu/webcam/sites/spruce16/
17	+9	ambient	http://phenocam.sr.unh.edu/webcam/sites/spruce17/
19	+0	elevated	http://phenocam.sr.unh.edu/webcam/sites/spruce19/
20	+2.25	ambient	http://phenocam.sr.unh.edu/webcam/sites/spruce20/

c. Networks or collaborations fostered: This project represents a long-term collaboration between the PIs of the DOE-funded SPRUCE project and the PhenoCam network.
d. Technologies/Techniques: This is the first time that PhenoCam technology has been used for long-term monitoring of experimental treatments, specifically the phenological impacts of elevated temperatures and elevated CO2.
e. Inventions/Patent applications: none.
f. Other products: none.