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Analysis of the uncertainty of phenological responses to climate change

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The seasonal recurring of phenological events, such as plant budburst, controls a whole range of climate system feedbacks and ecological interactions. In particular plant canopy development controls biosphere-atmosphere interactions through regulation of exchanges of carbon, water and energy. Phenological events have been shown to be highly sensitive indicators of the biological impacts of climate change. Based on previous studies, the IPCC's AR4 estimated an overall trend towards earlier spring of between 2.3 and 5.2 days per decade since the 1970s. However, the uncertainty in future phenological responses to climate change has not been rigorously quantified. Here we present the results of a data-model fusion experiment that leverages a unique, 20-year phenological dataset of direct observations of budburst of a wide range of native woody species growing at the Harvard Forest in central Massachusetts, with the aim of addressing the question of uncertainty in phenological forecasts.
A wide range of standard phenological spring onset models for 33 tree species have been parameterized using Monte Carlo techniques. Models are evaluated against the data using both cross-validation approaches and a standard, information-theoretic model selection criterion (Akaike's Information Criterion, AIC). For each model, an ensemble of acceptable parameter sets, characterizing the posterior parameter distributions, are generated by exploring parameter space and identifying those combinations that yield model output consistent with the observational data, based on a chi-squared test at 95% confidence. Running the models forward in time with this parameters ensemble provides a suite of probabilistic forecasts, with full characterization of prediction uncertainties. With the aim of assessing the potential effects of climate change on the phenology of the selected species, spring onset models have been ran from 1960 to 2099 using statistically downscaled GFDL climate projections for Harvard forest. We used two different carbon dioxide emissions scenarios: a1 and b1.
Differences among species in the model selected as the "best", conditional on the observational data, show that the mechanisms controlling spring budburst vary among species. AIC indicates good support for some common models, but little support for others. For individual models, species-specific parameterizations reveal highly variable sensitivities (across species) to temperature. Moreover, we show evidence that the response is often photoperiod-limited and not simply sensitive to warm temperatures in wintertime, this limits the degree to which budburst can advance. Based on variability across models, posterior parameter distributions and climatic drivers, the estimates of uncertainty have been partitioned in three components: model structure, model parameterization and climate scenario. Specifically we will show how uncertainties in predicted trends and simulated interannual variability differ among species and model structure. Finally we will conclude discussing different responses of phenology to different climate change scenarios.