Ranger Outline: We will come up with a better title when we feel more grounded in the results

Dan, Cat, Nacho and Lizzie

Figures to make:

1. Climate maps for species (some in supp. too)
2. Conceptual figure illustrating why variation in forcing should impact cue use
3. Results from cheapo models
4. some comparison of North America to Europe
5. Results from inter vs. intra specific model

Abstract

Introduction

For woody plants of the temperate zone the phenology, or annual timing, of spring budburst influences a myriad of ecological processes including patterns of resource allocation (), trophic interactions () and biogeochemical cycling (). Through budburst timing, woody plants balance the advantages of precocious growth resumption for resource gains with the risk of damage from late season frost (). To navigate this tradeoff, woody plants have evolved complicated networks of sensory organs, hormone signaling, and physiological responses to sense environmental cues; changes in their physical environment, that signal the arrival of appropriate conditions for resuming growth.

Decades of research suggest that warming spring temperatures (forcing), cool winter temperatures (chilling) and day length (photoperiod) are primary environmental cues utilized by woody plants that determine the timing of spring phenological events . These studies also demonstrate the there are substantial cue-use differences among species, with some species relying more heavily on some cues over others (**?**). As anthropogenic climate change has already driven shifts in spring phenology (), identifying these interspecific differences in cue use has emerged as a major goal of phenological research (). These differences have strong implications for both predicting the rate of phenological shifts as the climate continues to warm (), and anticipating the ecological consequences of these shifts ().

But the quantification of cue use difference among species offers even more—a novel opportunity to interrogate long-standing theories regarding the biology underlying cue-use difference among species. One particular relationship that can now be examined this the relationship species' geographic ranges and phenological cue use.

Climate is the major selective force on both species' geographic ranges () and their phenology (), and therefore, it is widely assumed that phenological cue-use differences among species reflect correlate with the climate of there repsecitve ranges (). That is, a species' relative reliance on forcing, chilling and photoperiod for each species should be shaped by the unique environmental conditions across a species' geographic range.

This has never really been tested (say better but see (**?**)). With the recent quantification for cue use of many species () and the accessibility of high resolution climate data it is now possible to rigorously test this theory with data. Below, we briefly review the specific assumptions and predictions presented in the literature about the relationship between phenological cue-use and species' range characteristics. We then test these predictions using Bayesian models for a large suite of temperate woody species from North America and Europe.

Assumptions and predictions for the relationship between the cue-use and species' ranges

0.0.1 Relative reliance

1. Assumptions:
   (a) Forcing is the predominant cure
   (b) Photoperiod and chill reliance evolves when forcing alone is not a reliable cue of safe growing condition (**?**).
   (c) Forcing is an unreliable cue where there is significant variation in it.
   (d) Specific prediction species with high variation in forcing in there range should have a stronger response to chilling and or photoperiod and a weaker sensitivity to forcing.
   (e) Yet, there are a few assumptions that need to be met in order to detect this signal if it is true.

      i. Among species cue variation is higher than withing (ie cue use is "conserved" at the species level)
      ii. There is coherance in forcing variation at multiple spatio-temporal scales.
         A. Intra-annual variation (Temp.var ggdlf)
         B. Inter-annual (cite Zohner) (Temp.var stv)
         C. local cliamte variation (Geo.var ggdlf)
         D. Deeper time stability () (literature)

E. global climate varaition (continents)

iii. Any of these level of varation could itself drive selecion for secondary cue usage (photoperiod/chilling) and it is unclear which is most important (**?**). If variation across these scales is not coherant clouding the signal.

(f) It may be also possible to test these hypotheses more indrectly through a range proxy.

(g) Rappenports Rule suggests that increased cliamted isntability correlates with larger range spcies. This has been show for Temperature trees in North America(**?**). If this is the case, species with larger ranges should have stronger chill/photoperiod cues

We tested these underlying assumptions aboutt he relationship between cliamte variables in a species ranges and specific predictions for the relationship between range cliamte and cue use using the OSPREE database, and climate data, and models.

Our interrogation of these relationships between climate and cue use not only clarifies the evolutionary drivers of cue use, but offers new insights regarding implications of climate change as both species' ranges and phenology continue to shift with warming.

Methods

Phenological data and cue-use estimates

Dan and/or Lizzie write:

- Introduce OSPREE
- Species selection
- Model description

Species' range characteristics

Cat and/or Nacho write?

- Climate data **(Figure of range maps with one climate variable, other could go to supplement)**
- note on temp vs. geographic variation
- calculation of GDD last frost
- STV
- range area

Statistical analysis

Variation and secondary cue use

Dan write description of cheapo models. Name them something cool.

Intra vs. interspecific models

Cat or Lizzie or Dan write

Results

Intra vs. interspecific

We found that inter-specific variation in cue us was higher than intraspecific.

Coherance of forcing variation

Like Fig 1 but with:

- gddlf.temp by ggdlf.geo
- stv by ggdlf.geo
- stv by ggdlf.temp
- area x ggdlf.temp

Climate variation and secondary cue use

Climate variation, cues and Rappenport rule

Discussion

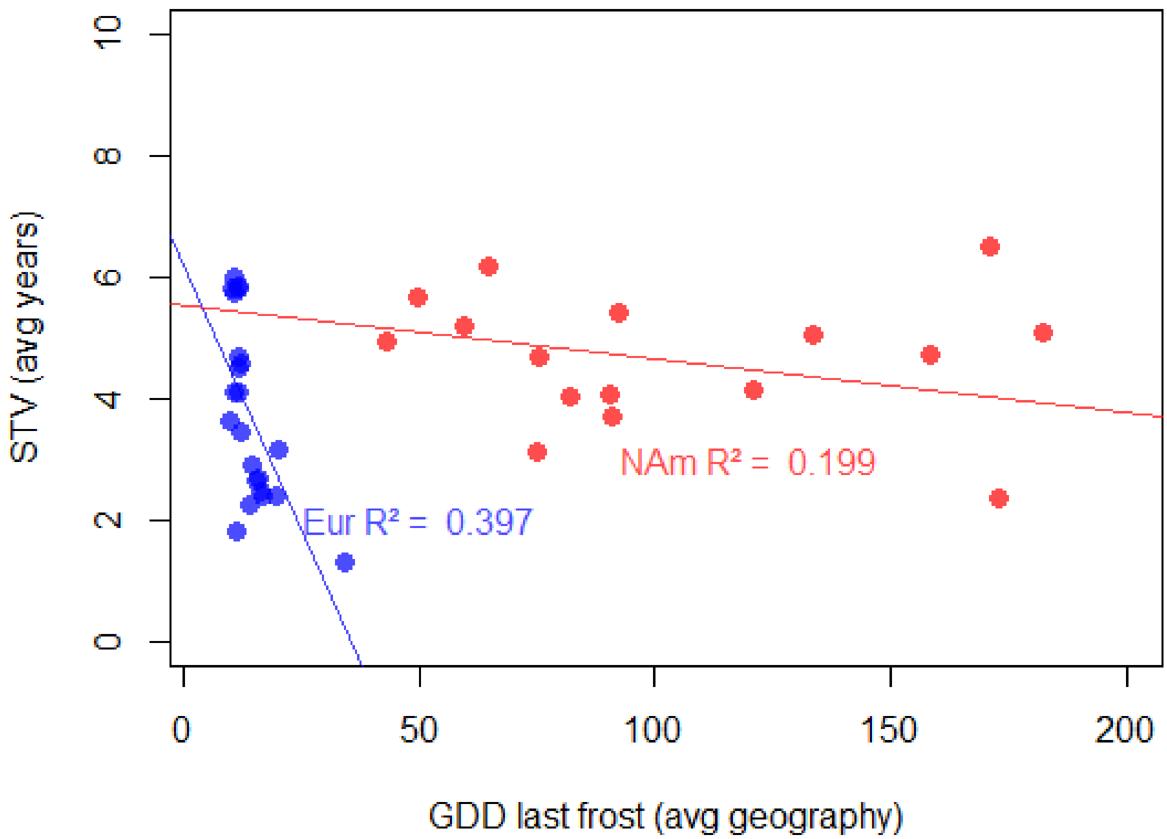

Figure 1: Correlations between levels of forcing variation. instead of this we'll SD$_g glf.temp X SD_g glf.geo, STV X SD_g glf.geo, stv by SD_g glf.temp, and maybe area by some of these things too.$