

RH: Interactive cues and spring phenology

Concept paper on understanding interactive cues and climate change (with growth chamber studies); or How interactive cues will drive climate change responses

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Abstract.— Goes here.

(Keywords: phenology, climate change, spring warming, forcing, chilling, daylength, photoperiod, non-linear responses, leafout, budburst)

1. Introduction

- (a) Climate change: it means all that work on phenology comes due ... now! (Short opening paragraph)
- (b) There has been a lot of focus on forcing but really it's more complicated
 - i. Think about one tree¹
 - ii. Look at its distribution!²
 - iii. Cues are adapted to high climate variation!
- (c) These cues may create critical non-linear responses that most current methods cannot predict, but measuring them and thinking about how they will interactively produce future phenology is hard because:
 - i. They are expected to interact; cues may compensate for other cues; meaning they mask one another
 - ii. They vary across species and possibly within species across the range
 - iii. They are hard to measure.³
- (d) How do you measure them there cues?
 - i. Methods especially lame at understanding these cues (and thus predicting non-linearities): models from long-term observational data ... somehow mention experiments maybe?
 - ii. Try to comment on the two issues at play here: the data type (e.g., long-term) versus the model type (e.g., linear and sans interactions?)
 - iii. The one method designed to look at all these cues is controlled environment (generally growth chamber) studies
- (e) Growth chamber studies
 - i. Can manipulate all three cues (and even more, humidity etc. nod?)
 - ii. Are often focused on interactions (unlike other methods)
 - iii. Have been done *forever*. But oddly, never really reviewed.
 - iv. ...and are often poorly integrated into current climate change literature. Including debates where they are critical, like about photoperiod.
- (f) Our aim is to:
 - i. Review how three major phenological cues for woody plant phenology will shift in coming decades with anthropogenic climate change

¹Here we pick one PEP725 species that is well-represented spatially for leafout or budburst data (Cat?)

²Here, we show a distribution map (Nacho?), maybe with some spring climate and/or phenology mapped on it.

³Somewhere in here need to sneak in that we will focus on woody species phenology, because it's where we understand things best and thus should build from there.

- ii. Review of the three major phenological cues from growth chamber studies over the past 60 (70?) years
 - iii. Highlight their critical relevance to climate change research
 - iv. Compare treatments from controlled environment studies to predicted shifts in cues with climate change.
 - v. Showcase how growth chamber studies can be best designed to better understand these interactive cues.
2. Random other bits to fit in
- (a) Fig: Number of studies by year (OSPREE)⁴
 - (b) Fig: Map of students, color coded or such by which of the three cues they manipulated
 - (c) Say something about material (seeds/saplings/cuttings)?
 - (d) Fig: Variation in treatments across space (photo/chill/force)
 - (e) Fig: Variation in treatments across time (graph with year on x -axis or divide time in half or such?)
 - (f) We need better non-linear models.
3. What cues will be most limiting with climate change?
- (a) Take each PEP725 datapoint within our selected species' range ...
 - (b) Calculate:

We need to think about this a lot more! Do we want to do? And if so, exactly what metrics do we want?

 - i. Min daily temp for 1-2 months before leafout
 - ii. Max daily temp for 1-2 months before leafout
 - iii. Chilling units (which?) for Oct-February ... actually, if we just want to do simple comparisons to the OSPREE data (and I think we do), then we could just do min/max temperatures (and mean?) for Oct-February I think!
 - iv. Most directly comparable to OSPREE would be daily min and max temperatures I think; might also be important to use daily min/max if we are focused so closely on getting things accurate. But we should discuss how feasible this is.
4. Wrap-up....

⁴Other ideas: number of species studied by year. Show crops or remove or show separately?