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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

The lab[1,2]

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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 tree[1]

      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

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

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

[3] Somewhere 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. Review how cues will shift with climate change (we could have figures of change in temp across the distibution here?)
   (a) Forcing: the world will get warmer
      i. Higher altitude and arctic places will warm more
      ii. Give range of warming depending on different scenarios
      iii. Minima warm more than maxima (night-time temps)
   (b) Chilling, see forcing but ...
      i. Chilling only occurs between certain temps so some places accumulate more chilling with warming
      ii. And there is so much we don't know about how chilling works and interacts with forcing (sequential model, parallel models etc.)
   (c) Photoperiod: Shifts with phenology
      i. Changes in forcing and chilling will alter the photoperiod that matters so to speak
      ii. Need more here ...

3. Review of the three major phenological cues from growth chamber studies over the last 67 years
   (a) Quick intro to the data, how long, which cues ....
      i. Fig: Number of studies by year (OSPREE)[4]
      ii. Fig: Map of studies, color coded or such by which of the three cues they manipulated
   (b) For each of the three cues:
      i. X% of studies manipulated that cue
      ii. Variation across space, continent and time (and species)?
      iii. Fig: Variation in treatments across space (photo/chill/force)
      iv. Fig: Variation in treatments across time (graph with year on x-axis or divide time in half or such?

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

(c) X% of studies manipulated which interacting cues? (i.e., how many studies manipulate 1 cues, 2 cues, 3 cues ... of those manipulating 1 cue, what is the breakdown by cue etc.)

4. Random other bits to fit in

   (a) Say something about material (seeds/saplings/cuttings)?

   (b) We need better non-linear models.

5. 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.

6. Wrap-up....