

Let's answer when/how/why growing season length and growth
relate!

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Contents

1	To remember when we pick this outline up after the table is done	1
2	What to do next or some day ...	2
3	Outline	2
4	Figure ideas	6

1 To remember when we pick this outline up after the table is done

We're interested in constraints, resource limitations, species and interdisciplinarity; we should stay focused on this.

- Interdisciplinary needed, especially to address hypotheses of resource limitation versus constraint
 - Semantic issues make it difficult to know what is or has been tested
 - Everyone is measuring stuff in a slightly different way makes it really hard to compare (especially when everyone is doing only part of the diagram)
 - Boring thing about growing season length: Which to measure? Actual growth end/start as growth (but which growth) or phenological start/end ...
- Full path diagram of what is happening is more complicated than perhaps is being let on, and no one has tested it fully
 - Path diagram figure
 - * Start simple: temp → GSL → growth (this was NEP x growth studies from a while ago; and the tree ring people go backwards along this diagram)
 - * Next: Just the conceptual: temp → GSL → growth PLUS resource bubble

- * Supp figure on measurements? Figure with methods layered on, maybe do just for start and end of GSL or such
- * Layer onto this figure: What each fields offer – size of arrow is the number of studies that do it
- * Layer onto this figure: What each field could offer if they did x, y, z – FUTURE directions also
- * We need relative magnitude of these arrows
- Figure of ideal workflow?
- Figure of concepts versus methods
- Okay, how would you test the full workflow
- The provenance people have a lot to offer but they don't measure annual growth ... they have the constraint information, but asking it for a different reason.
- Could they manipulate temp and resource?
- Or we need the tree ring people to work on this: tree rings across distribution → response + variability of response
- Greenhouse/growth chamber folks can do the full figure
- Species! Species differences – keep thinking about where to fit this in; can we look at representativity across tree ring / phenology / experiments (mention competition in future directions; we have to get a handle on this conceptual diagram first)

2 What to do next or some day ...

1. Review our old notes and outlines
2. Fill out table Janneke is making ... what do we want out of it?
3. How to review the papers (pick them) for Janneke's table
4. Measurement comparisons: growth estimated from tree rings (climatology), tree rings (ecology), tree rings in experiments or such?
5. Why is the Parent et al. 2012 curve different than Alan's curves for A_{net} ?

3 Outline

Translator:

1. GSL: growing season length
2. RL: resource limitation
1. Introduction (what's happened in the past and where this paper goes)

- (a) Unexpected controversy over GSL and tree growth _____ needs organizing
 - i. Basics: GDD model of growth suggests GSL x growth (with some base temperature for GDD)
 - ii. Back when: Ecosystem scale growth (NPP?) increases with warming
 - iii. New studies: Tree rings don't show GSL x growth (ring width)
 - iv. But ... Tree ring old studies do show GSL x growth (ring width) _____ Do they?
Need refs
 - (b) What's going on?! (Briefly)
 - i. Measurement issues
 - ii. Biophysical constraints
 - iii. Resource limitations
 - (c) Here, we. ...
 - i. Our premise is that some hypotheses for what's going may be tractably already answered by combining data across fields/methods
 - ii. Is our premise also that constraint issues are not well included in current hypotheses?
 - iii. And, you could go far by cross-field tweaking of what each field is doing
 - (d) This is important! _____ fit this
into intro
 - i. Carbon storage and climate change
 - ii. Fundamental to physiology, species assembly
2. Section: Review three reasons for not growing (Our opinion on now)
- (a) Overview paragraph of three reasons
 - i. measurement – see box (include measurement only here, maybe)
 - ii. Resource limitation
 - iii. Constraints
 - (b) Resource limitation, evidence for an against _____ we need
to go back
to liter-
ature to
work on
this
 - i. Nutrients
 - ii. Water
 - iii. Is this more species-specific?
 - (c) Constraints, evidence for an against _____ we need
to go back
to liter-
ature to
work on
this
 - i. Leaf life span
 - ii. Budset stuff ... (Zohner, Sool.)
 - iii. Evidence across species? Or which is species-specific
3. What do do next (The future! Is there a framework to our future directions? It would be nice if we found one)
- (a) Tree ring people should ... get better phenology data and a better sampling design ... and figure out the transfer $f(x)$

- i. core trials with phenology data
 - ii. PEP725 x ITRB plot – sampling overlap; sample more places/species with phenology data
 - iii. Take more fine-scale measurements
- (b) Permanent plot data (provenance/forestry plots) need some temporal resolution and need more allometry data
 - i. Do they have GSL?
 - ii. They calculate growth every 5 years, they need annual data!
 - iii. Allometry here is big opportunity: measuring at different heights (more fine-scale data)
- (c) Greenhouse/chamber experiments
 - i. Our experiment (which needs a name)!
 - ii. VPD x temperature curves – figure those out, include more xylogenesis here
- (d) Big experiments
 - i. You could do one for this topic
 - ii. Measure GSL and tree rings in other ones: FACE, Phynwald, Rainout things, SPRUCE
- (e) Constraint experiments (yes, messy topic ... not sure where all this goes ...)
 - i. Give plants everything they want and show they still shut down growth at the same time (this goes with some full factorial experiments with drought etc. so we could estimate when the constraint matters ... we could say 'of course there is a constraint but we need to better understand when it would matter with climate change)
 - ii. How do people show constraints?
 - A. You sort of need the mechanism ... molecular, experiment on proximate cues etc.
 - B. Show variation across latitude often for this

Feelings & thoughts coming up

1. If you want to resolve this debate, you need comparable estimates – you have to report similar models (you
2. Some of the fields (tree rings, where we found so far studies do not look consistently at growing season length x growth, they are more interested in spring temperatures x growth) do not care as much about the mechanism... but it really matters
3. Very difficult to compare studies as terms are defined differently (e.g., growing season length) ... could compare what the terms mean across fields
4. Two major ways to measure growing season length: phenological and growth data (xylogenesis)

Wait, WTF is a constraint? Or is there a gradient of constraint to RL ...

1. Lifespan determination growth mush
 - (a) Seasonal growth stops: Budset, Zohner equinox paper
 - (b) Does high temperature fit here? (Definitely on a different timescale)
2. High temperature limitation – enzymatically it's over
3. Low temperature limitation – sort of like energy limitation
4. Things we feel sure are resource limitation
 - (a) Nutrients
 - (b) Water
5. Terms we could use. ...
 - (a) Phenomenological without a real mechanism (plants stop growing at the same time every year)
 - (b) External versus internal
 - (c) Abiotic versus biotic
6. Kavya adds: I was thinking a little more about the whole constraints vs. limitation thing and this is a thought I had: Is the distinction between resource limit and constraint that resource limitation occurs across a spectrum while constraints have more rigid boundaries (even for the same organism)? In this case (and following Alana's cool figure), temp could be both — at the two ends of the spectrum it's a constraint (cannot photosynthesize below or above a threshold (enzymatic limits)) but in the middle, it's a resource limitation? Or maybe up till T_{opt} it's a resource limit and beyond that it becomes a constraint? Also I think it would be good for us to distinguish between net C uptake and allocation to growth? As in trees might still be photosynthesizing but not growing, or not growing in the ways we think they would. Or maybe this just goes into the measurement box with the idea that we aren't measuring the correct/all of the facets of growth.
7. Janneke then added: problem is that temperature influences the rate of everything to do with growth and resource uptake (e.g., water and nitrogen) and is also a damaging agent (e.g., frost, denaturing)

Things that need a home

1. Patterns of GSL x growth across elevation/latitude
2. What is growing season length? (Actually when growth starts? Or something else?)
3. Measurement issues
 - (a) Maybe they are growing and you measured the wrong thing

- (b) What scale of effect can we detect (and do we expect)?
- (c) Maybe we are measuring the wrong species ...
- 4. Conifers (tree ring data) versus deciduous (phenology data)
- 5. Conifers: Does leafout matter in conifers or would it be much more related to when they start photosynthesizing with old leaves?
- 6. Species diversity in tree ring studies ... maybe make table on whether the studies with tree rings and growth have looked at dominant canopy species
- 7. Maybe ... which species have budset constraints been shown in?

add to
Janneke's
table?

4 Figure ideas

- 1. Ruben's figure
- 2. Alana's rate x temperature (x limitations) figure: maybe add in agriculture
- 3. ISI cross-pollination currently across fields
 - (a) tree rings in climatology
 - (b) tree rings in ecology
 - (c) constraint folks
 - (d) forestry plots (provenance trials)
 - (e) experiments ...
- 4. PEP725 x ITRB plot
- 5. Figure for future part?
- 6. Table/figure on advantages/limitations for each approach? Key places where interdisciplinary opportunities (leverage)