The role of information in anticipatory responses

A possible framework for its analysis

Pedro J. Aphalo

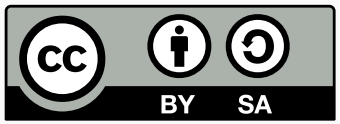
Joensuu, 29 June 2016

Department of Biosciences, University of Helsinki

and

Viikki Plant Science Center, University of Helsinki

Department of Biosciences, University of Helsinki, Finland.
http://blogs.helsinki.fi/senpep-blog/



Outline

Background

An evolutionary viewpoint

- The focus of my presentation will be the sensory abilities of plants from an evolutionary and fitness perspective.

An evolutionary viewpoint

- The focus of my presentation will be the sensory abilities of plants from an evolutionary and fitness perspective.
- Fitness represents an *ultime cause* (a *why* question).

An evolutionary viewpoint

- The focus of my presentation will be the sensory abilities of plants from an evolutionary and fitness perspective.
- Fitness represents an *ultime cause* (a *why* question).
- The physiological and/or molecular mechanisms are *proximate causes* (*how* questionss).

An evolutionary viewpoint

- The focus of my presentation will be the sensory abilities of plants from an evolutionary and fitness perspective.
- Fitness represents an *ultime cause* (a *why* question).
- The physiological and/or molecular mechanisms are *proximate causes* (*how* questionss).
- In animal ecology sensory ecology is an important discipline.

An evolutionary viewpoint

- The focus of my presentation will be the sensory abilities of plants from an evolutionary and fitness perspective.
- Fitness represents an *ultime cause* (a *why* question).
- The physiological and/or molecular mechanisms are *proximate causes* (*how* questionss).
- In animal ecology sensory ecology is an important discipline.
- In the case of plants this approach has been rarely used...

An evolutionary viewpoint

- The focus of my presentation will be the sensory abilities of plants from an evolutionary and fitness perspective.
- Fitness represents an *ultime cause* (a *why* question).
- The physiological and/or molecular mechanisms are *proximate causes* (*how* questionss).
- In animal ecology sensory ecology is an important discipline.
- In the case of plants this approach has been rarely used...
- ...based on the assumption that sensory capabilities and specially information processing are very limited in plants.

An evolutionary viewpoint

- The focus of my presentation will be the sensory abilities of plants from an evolutionary and fitness perspective.
- Fitness represents an *ultime cause* (a *why* question).
- The physiological and/or molecular mechanisms are *proximate causes* (*how* questionss).
- In animal ecology sensory ecology is an important discipline.
- In the case of plants this approach has been rarely used...
- ...based on the assumption that sensory capabilities and specially information processing are very limited in plants.
- Now we know that this assumption does not hold.

Forecasting: its relation to fitness

- The discussion of the role “future perception” in fitness is current (Novoplansky 2016).

Forecasting: its relation to fitness

- The discussion of the role “future perception” in fitness is current (Novoplansky 2016).
- We depend on informally forecasting all sorts of events every minute.

Forecasting: its relation to fitness

- The discussion of the role “future perception” in fitness is current (Novoplansky 2016).
- We depend on informally forecasting all sorts of events every minute.
- Sometimes we do this consciously, but most of the time we are not aware of what our brain is doing.

Forecasting: its relation to fitness

- The discussion of the role “future perception” in fitness is current (Novoplansky 2016).
- We depend on informally forecasting all sorts of events every minute.
- Sometimes we do this consciously, but most of the time we are not aware of what our brain is doing.
- We use forecasts at very different time scales and to many different ends.

Forecasting: its relation to fitness

- The discussion of the role “future perception” in fitness is current (Novoplansky 2016).
- We depend on informally forecasting all sorts of events every minute.
- Sometimes we do this consciously, but most of the time we are not aware of what our brain is doing.
- We use forecasts at very different time scales and to many different ends.
- If we use the abstraction of information, and for a moment forget about how its processing is implemented...

Forecasting: its relation to fitness

- The discussion of the role “future perception” in fitness is current (Novoplansky 2016).
- We depend on informally forecasting all sorts of events every minute.
- Sometimes we do this consciously, but most of the time we are not aware of what our brain is doing.
- We use forecasts at very different time scales and to many different ends.
- If we use the abstraction of information, and for a moment forget about how its processing is implemented...
- ...it is easy to imagine that every organism must have evolved the capacity to “forecast” future events important for fitness.

Forecasting: its relation to fitness

- The discussion of the role “future perception” in fitness is current (Novoplansky 2016).
- We depend on informally forecasting all sorts of events every minute.
- Sometimes we do this consciously, but most of the time we are not aware of what our brain is doing.
- We use forecasts at very different time scales and to many different ends.
- If we use the abstraction of information, and for a moment forget about how its processing is implemented...
- ...it is easy to imagine that every organism must have evolved the capacity to “forecast” future events important for fitness.
- How information is processed, “the machinery used”, does not need to be the same as long the information is acquired, transmitted, stored and combined successfully.

Can plants forecast? Preemptive acclimation

- Several plant responses can be only explained from the evolutive/fitness point of view as being a ‘preparation’ to tolerate or escape future stress events or take advantage of future favourable conditions.

Can plants forecast? Preemptive acclimation

- Several plant responses can be only explained from the evolutive/fitness point of view as being a ‘preparation’ to tolerate or escape future stress events or take advantage of future favourable conditions.
    - Example 0: Phenology.

Can plants forecast? Preemptive acclimation

- Several plant responses can be only explained from the evolutive/fitness point of view as being a ‘preparation’ to tolerate or escape future stress events or take advantage of future favourable conditions.
  - Example 0: Phenology.
  - Example 1: Preemptive shade avoidance as a response to reflected far-red light from neighbouring plants.

Can plants forecast? Preemptive acclimation

- Several plant responses can be only explained from the evolutive/fitness point of view as being a ‘preparation’ to tolerate or escape future stress events or take advantage of future favourable conditions.
  - Example 0: Phenology.
  - Example 1: Preemptive shade avoidance as a response to reflected far-red light from neighbouring plants.
  - Example 2: Eavesdropping-on/communicating-with neighbours to preemptively acclimate/prepare for drought, herbivore attacks, even to synchronize flowering among individuals.

Can plants forecast? Preemptive acclimation

- Several plant responses can be only explained from the evolutive/fitness point of view as being a ‘preparation’ to tolerate or escape future stress events or take advantage of future favourable conditions.
  - Example 0: Phenology.
  - Example 1: Preemptive shade avoidance as a response to reflected far-red light from neighbouring plants.
  - Example 2: Eavesdropping-on/communicating-with neighbours to preemptively acclimate/prepare for drought, herbivore attacks, even to synchronize flowering among individuals.
  - Example 3: Possibly (a hypothesis) preemptive acclimation to future soil drying in response to high ultraviolet-B irradiance.

Why sensory ecology?

What sensory ecology tells us

1. Information sources are crucial to the performance and survival of organims...

What sensory ecology tells us

1. Information sources are crucial to the performance and survival of organims...
2. ...$\Rightarrow$ cross-correlations among variables in their environment and their lags, and autocorrelations, are key sources of information

What sensory ecology tells us

1. Information sources are crucial to the performance and survival of organims...
2. ...⇒ cross-correlations among variables in their environment and their lags, and autocorrelations, are key sources of information
3. ...⇒ we need to pay attention to 'joint statistical properties of environmental variables'...

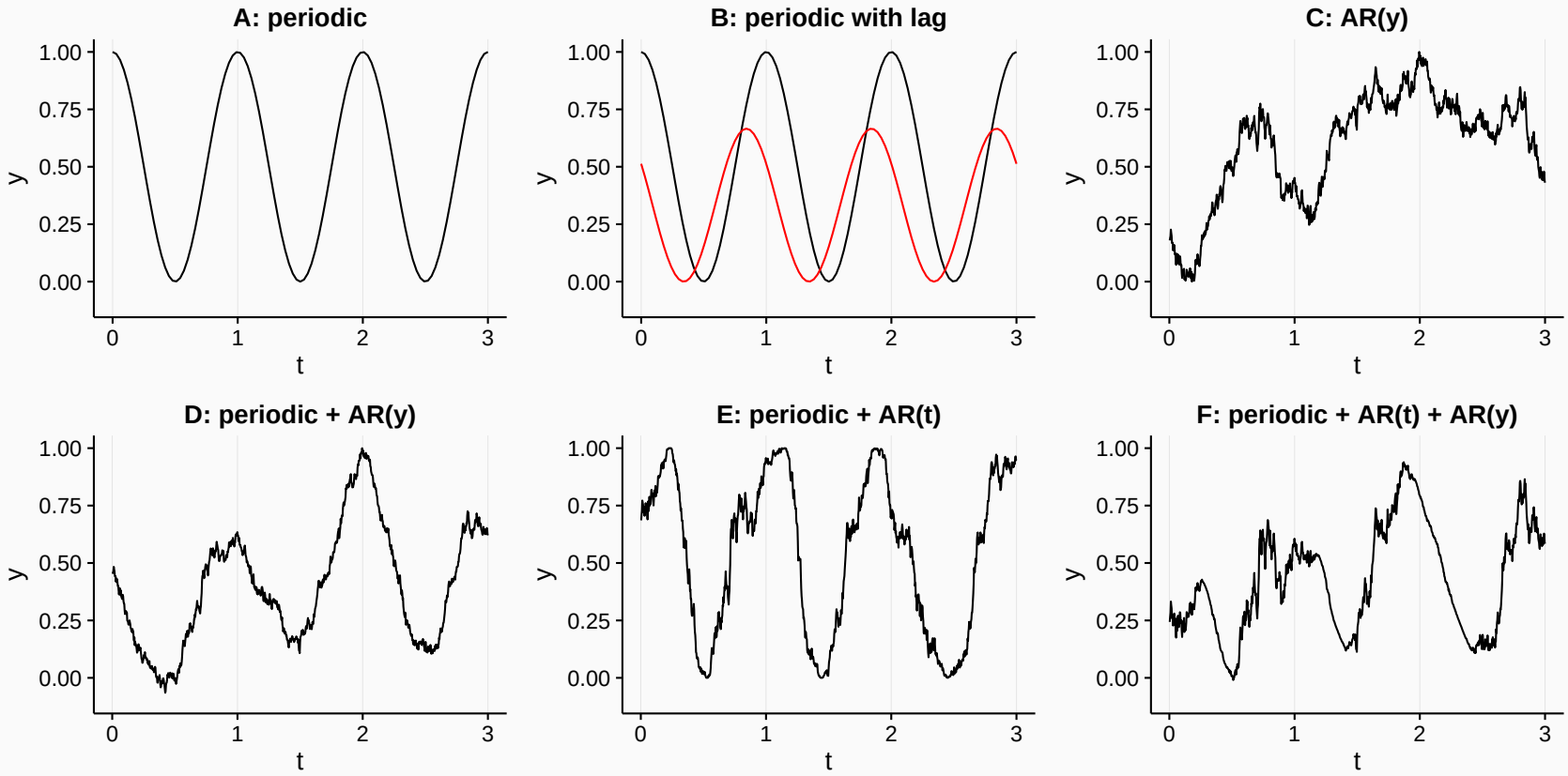
What sensory ecology tells us

1. Information sources are crucial to the performance and survival of organims...
2. ...⇒ cross-correlations among variables in their environment and their lags, and autocorrelations, are key sources of information
3. ...⇒ we need to pay attention to 'joint statistical properties of environmental variables'...
4. Could we pay more attention to sources of information?

What sensory ecology tells us

1. Information sources are crucial to the performance and survival of organims...
2. ...⇒ cross-correlations among variables in their environment and their lags, and autocorrelations, are key sources of information
3. ...⇒ we need to pay attention to 'joint statistical properties of environmental variables'...
4. Could we pay more attention to sources of information?
5. ...and how sensory mechanisms have been "tuned" by evolution to filter information from noise?

Correlations in the environment



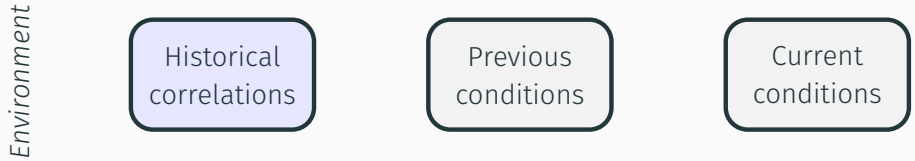
A possible framework

Proposed theoretical framework (I)

Conceptual framework

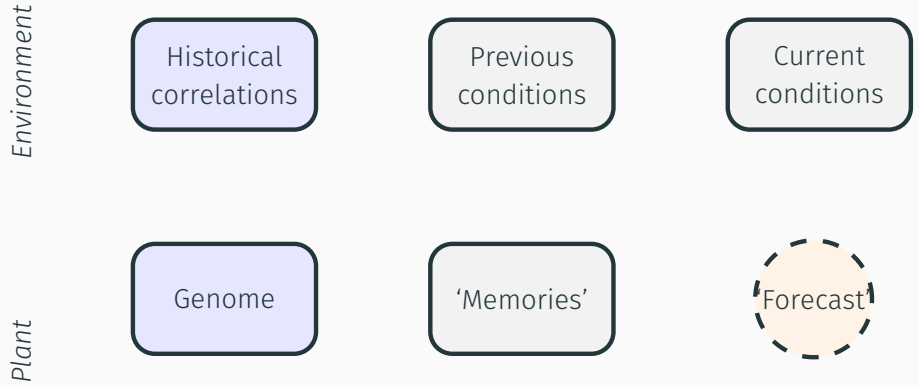
Proposed theoretical framework (I)

Conceptual framework



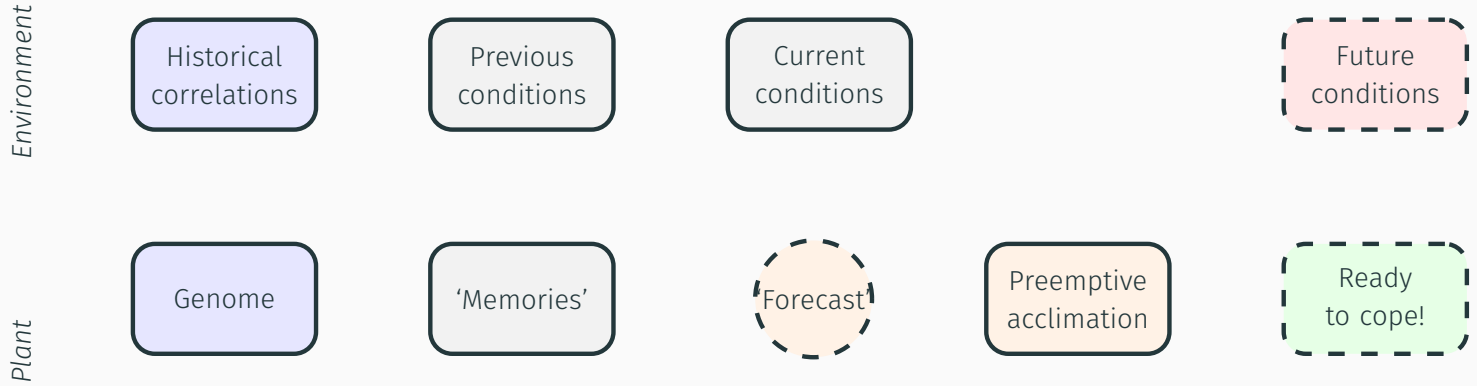
Proposed theoretical framework (I)

Conceptual framework



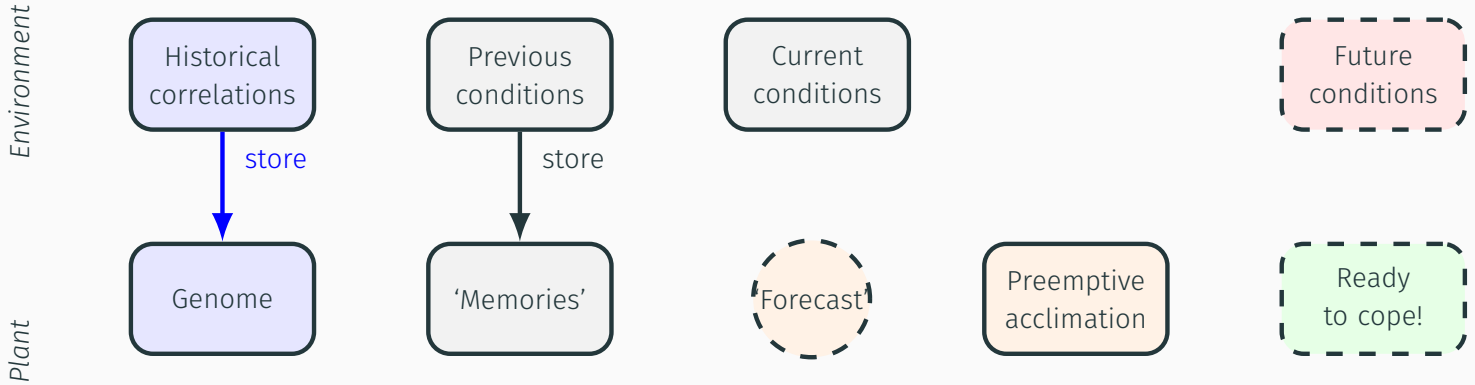
Proposed theoretical framework (I)

Conceptual framework



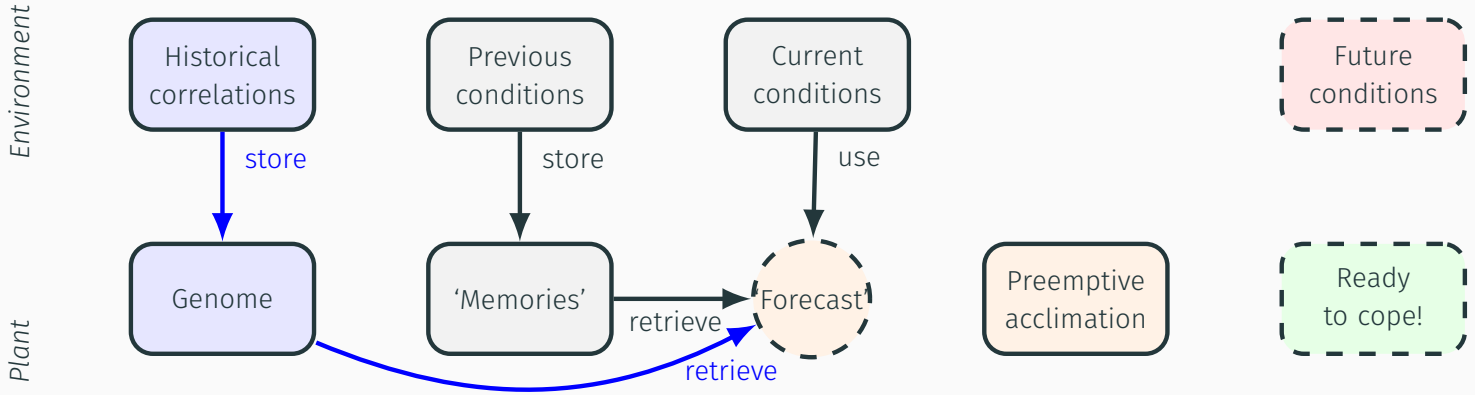
Proposed theoretical framework (I)

Conceptual framework



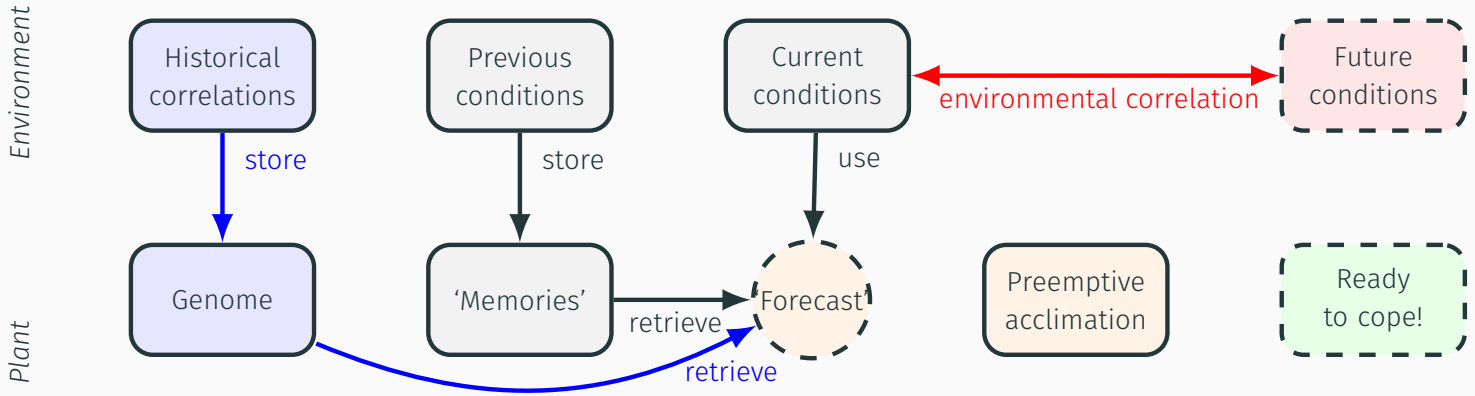
Proposed theoretical framework (I)

Conceptual framework



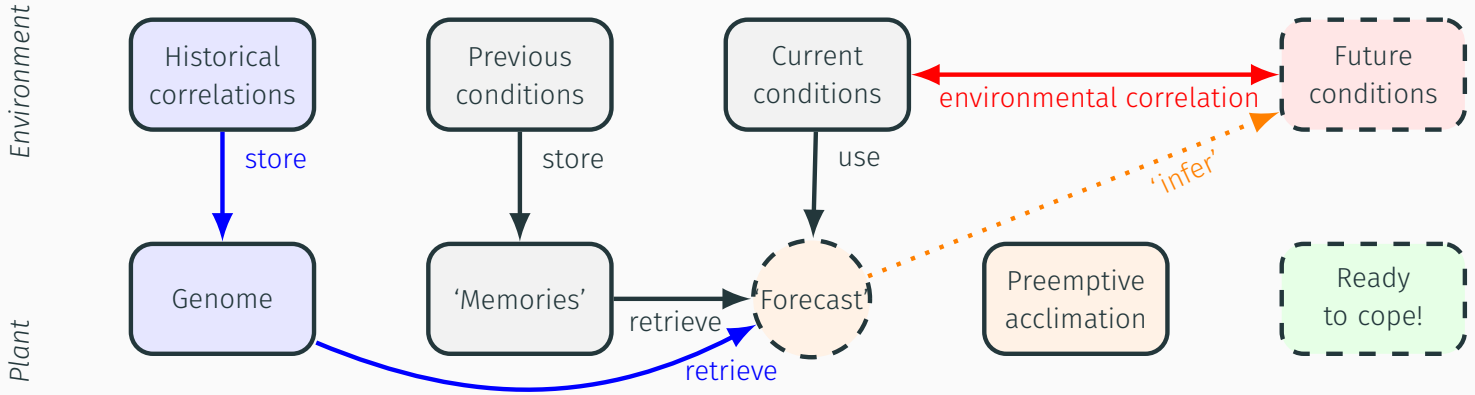
Proposed theoretical framework (I)

Conceptual framework



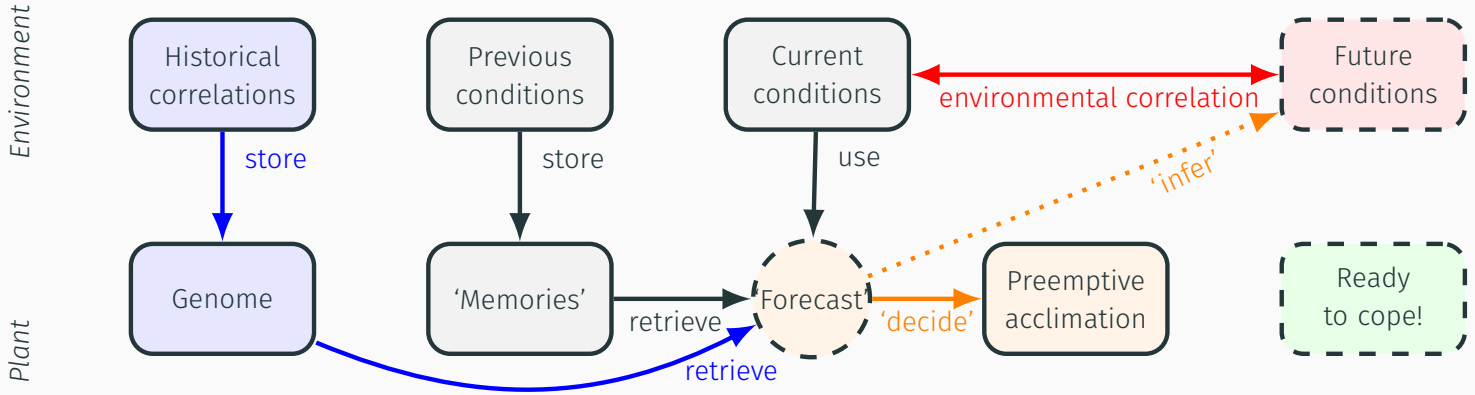
Proposed theoretical framework (I)

Conceptual framework



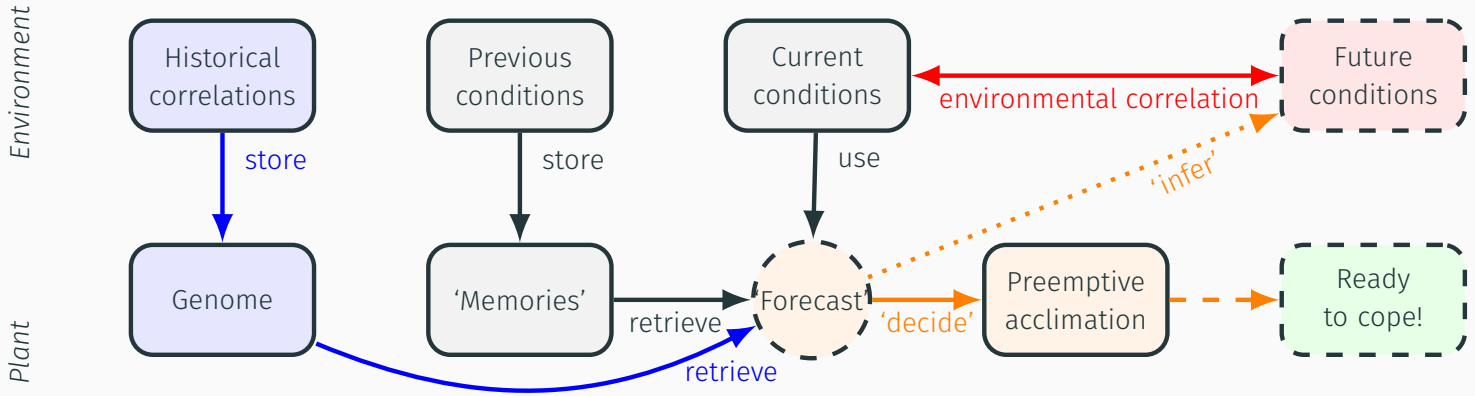
Proposed theoretical framework (I)

Conceptual framework



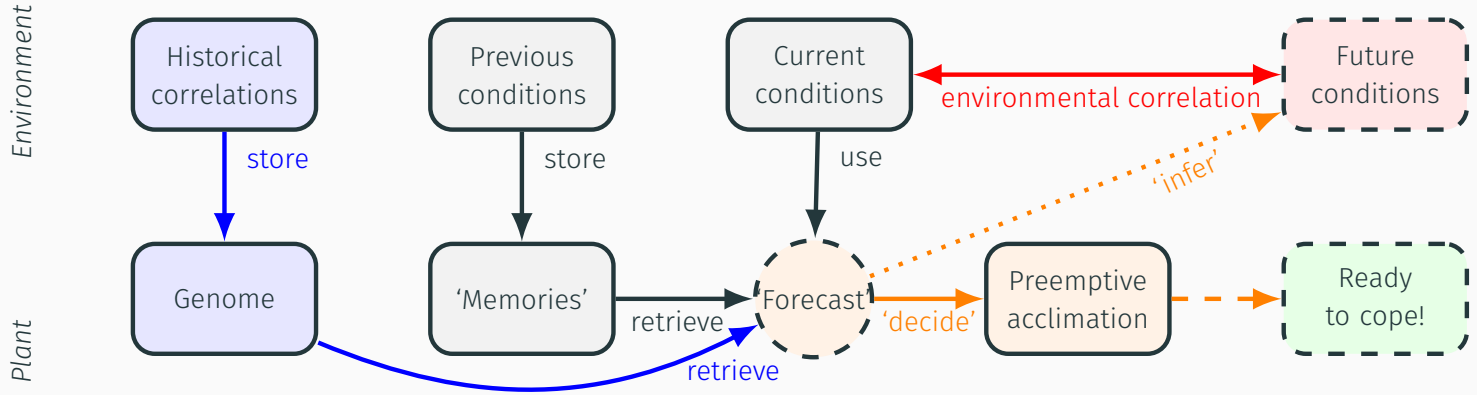
Proposed theoretical framework (I)

Conceptual framework

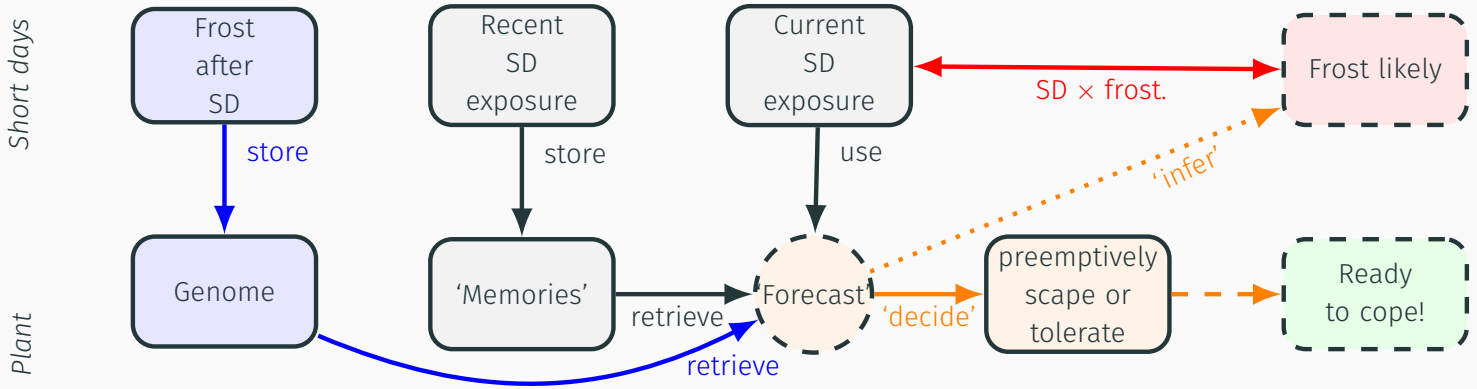


Proposed theoretical framework (I)

Conceptual framework

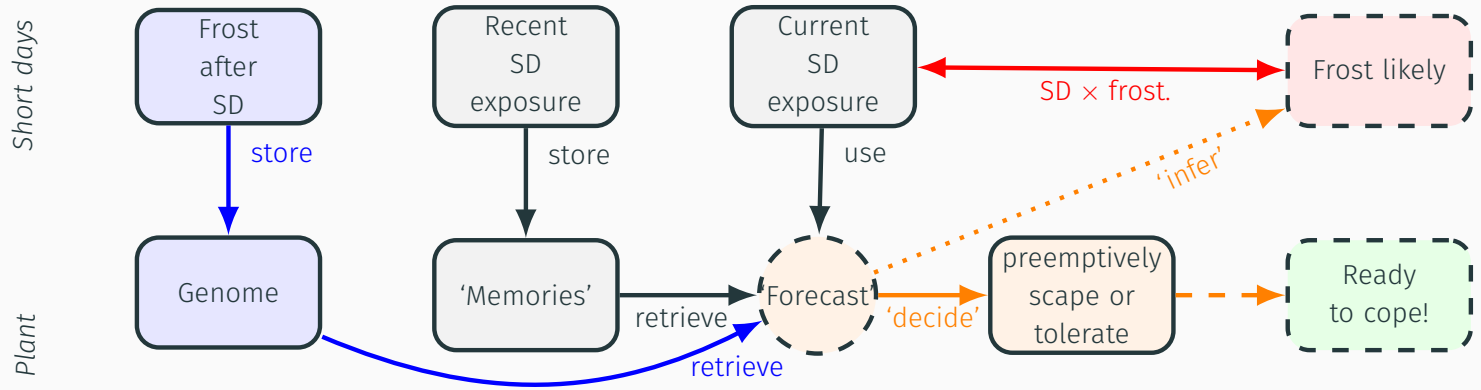


Example: Frost hardening



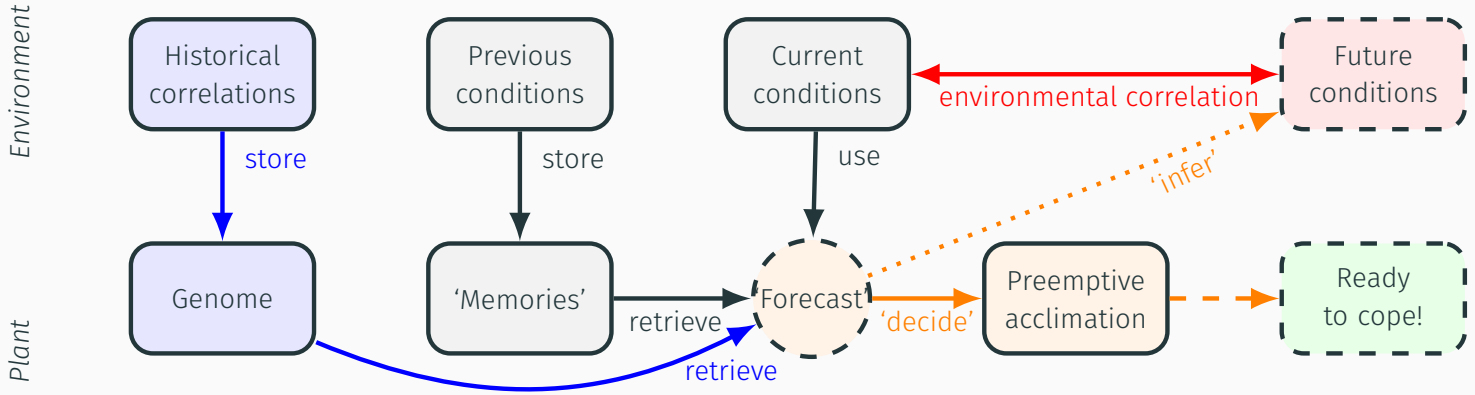
Proposed theoretical framework (I)

Example: Frost hardening



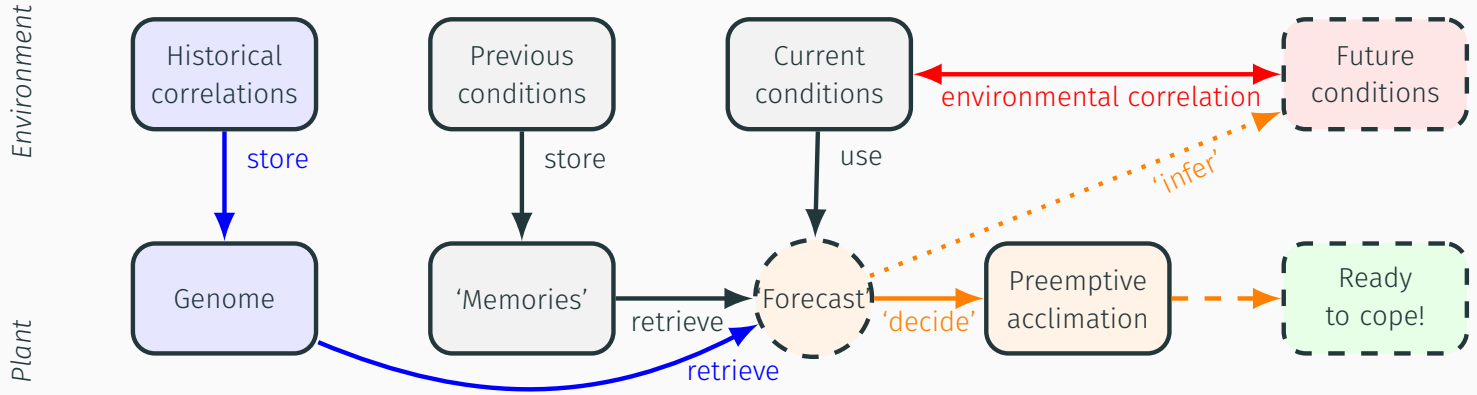
Proposed theoretical framework (II)

Conceptual framework

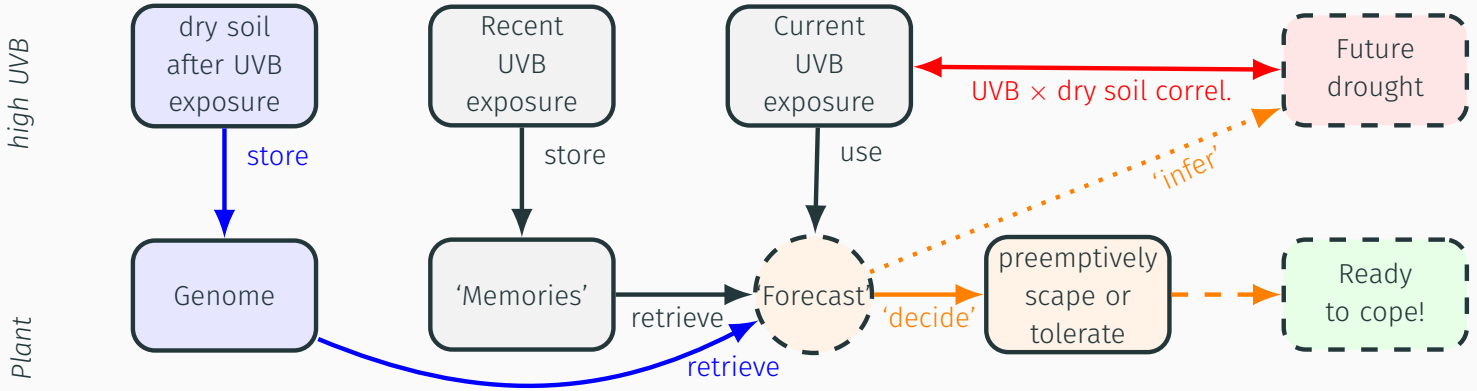


Proposed theoretical framework (II)

Conceptual framework

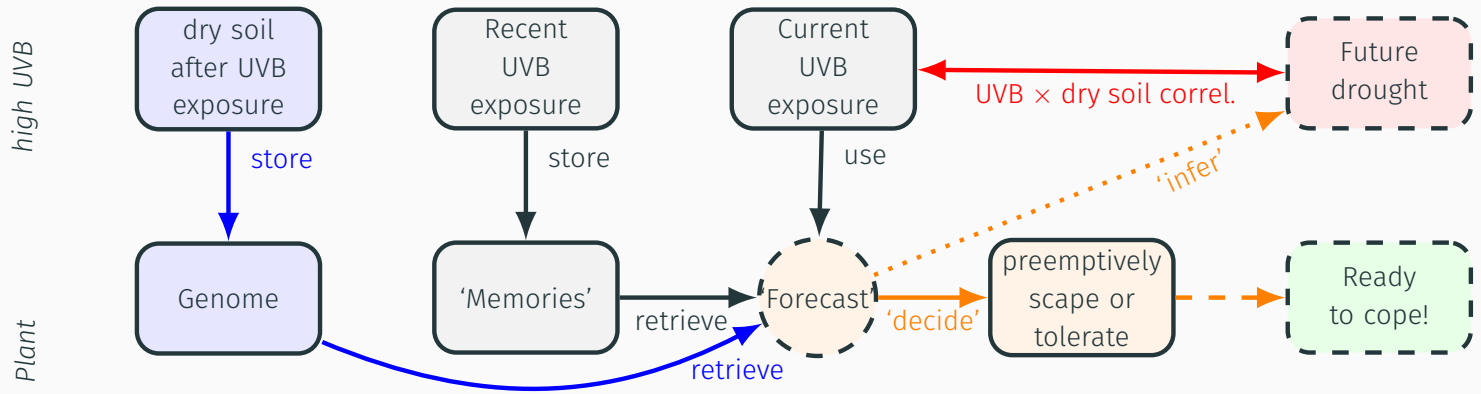


UVB example



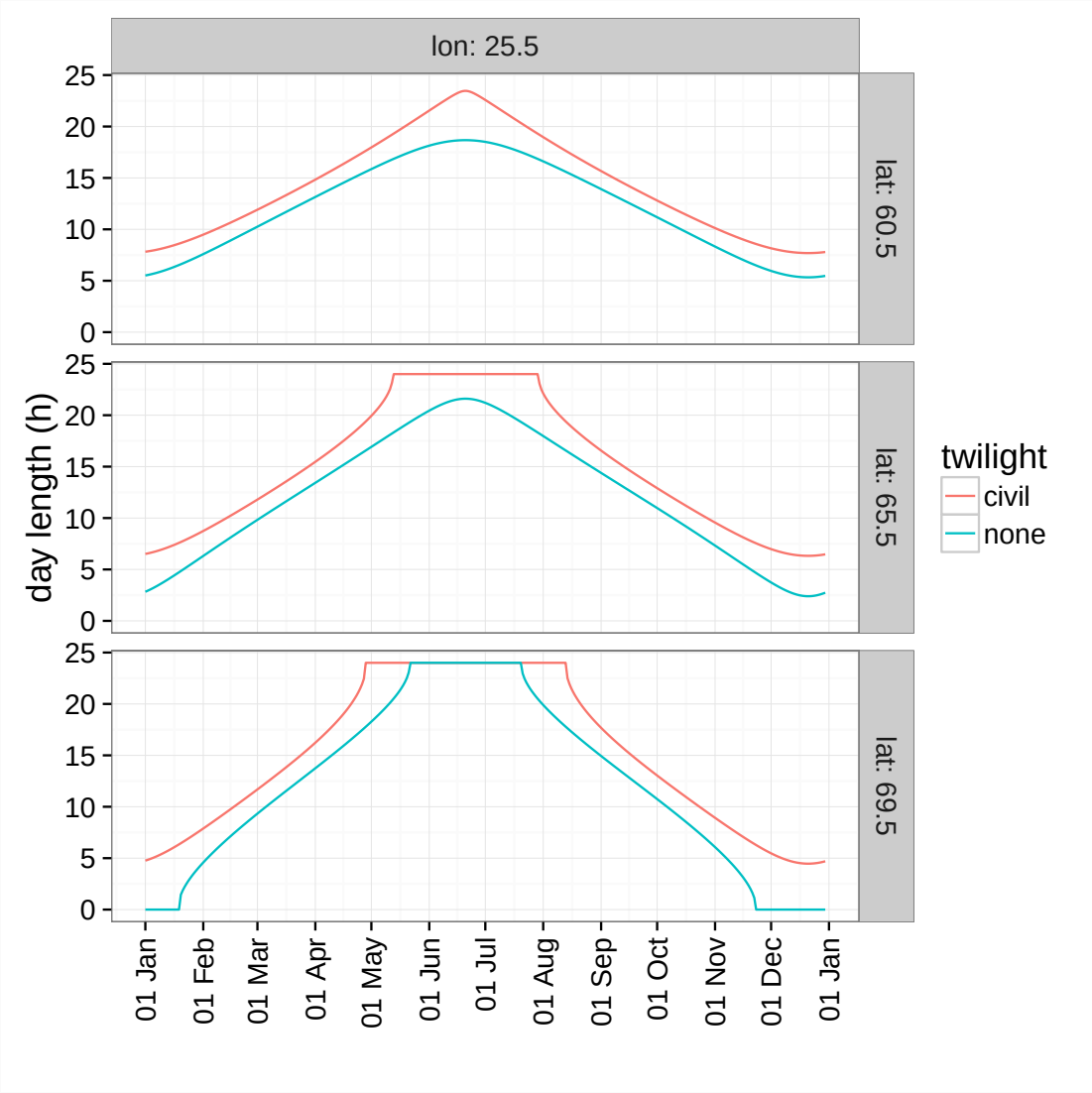
Proposed theoretical framework (II)

UVB example

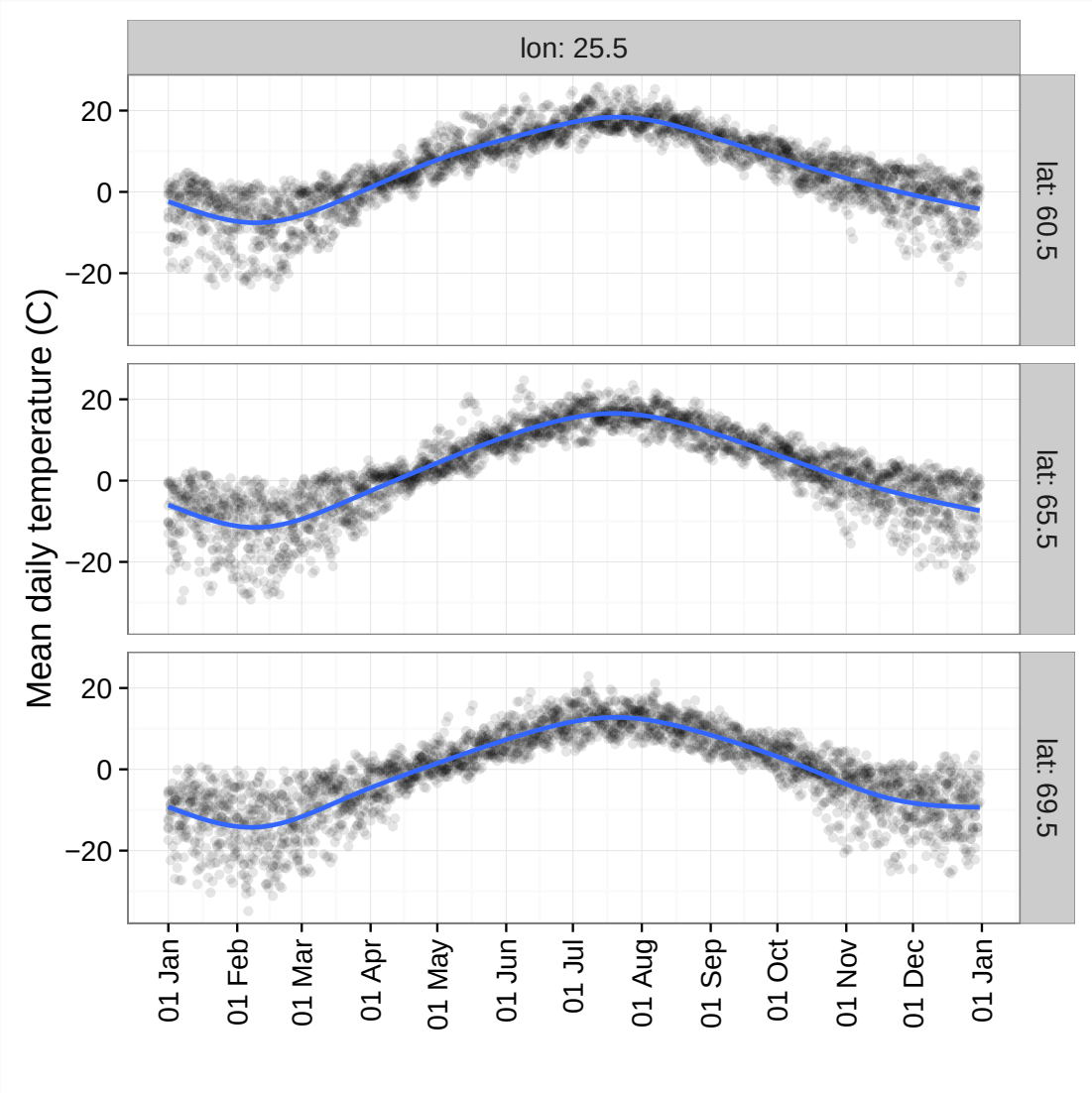


Some variables familiar to all of you

Day length and twilight

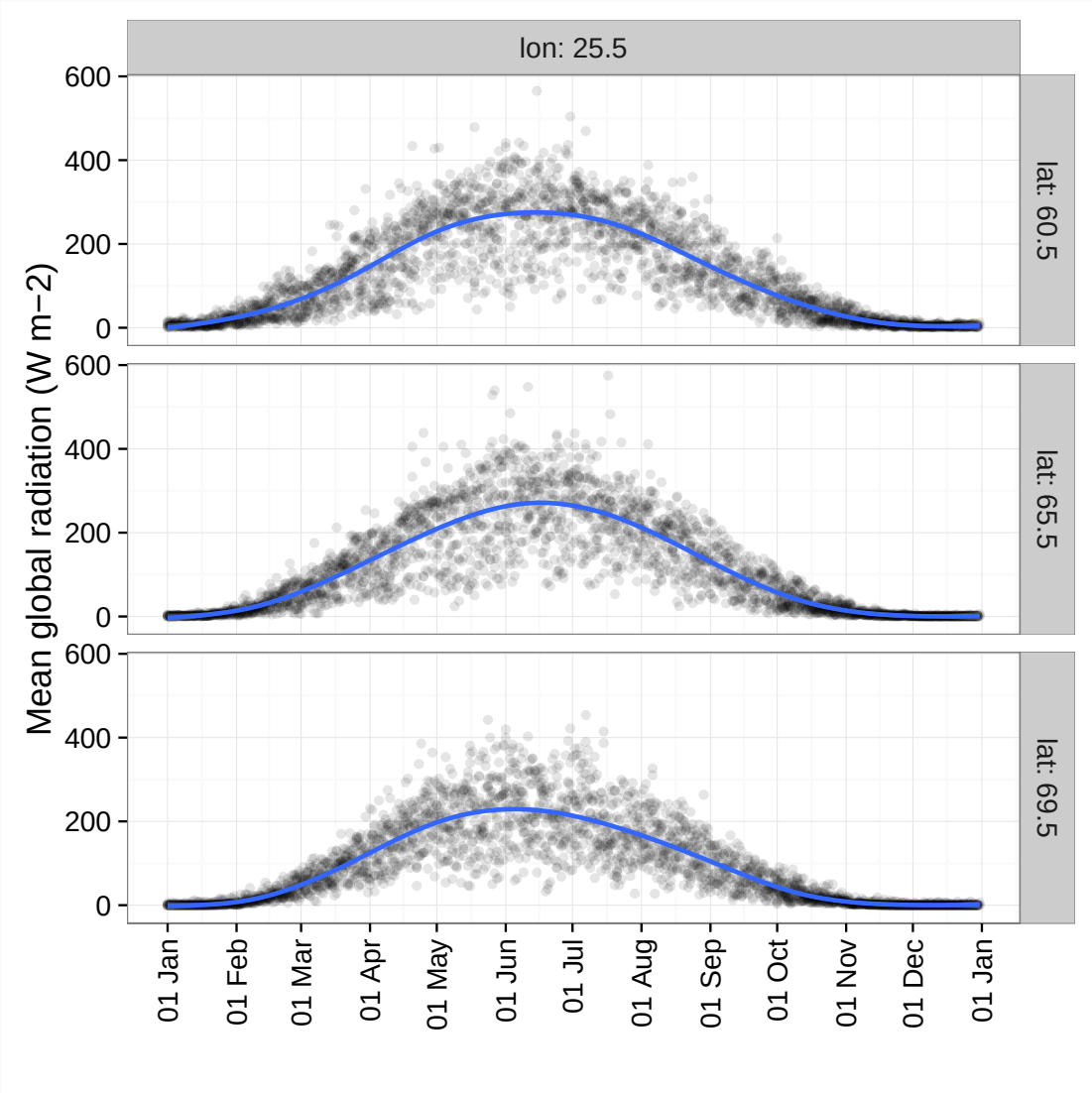


Temperature and its variability: 2004–2014



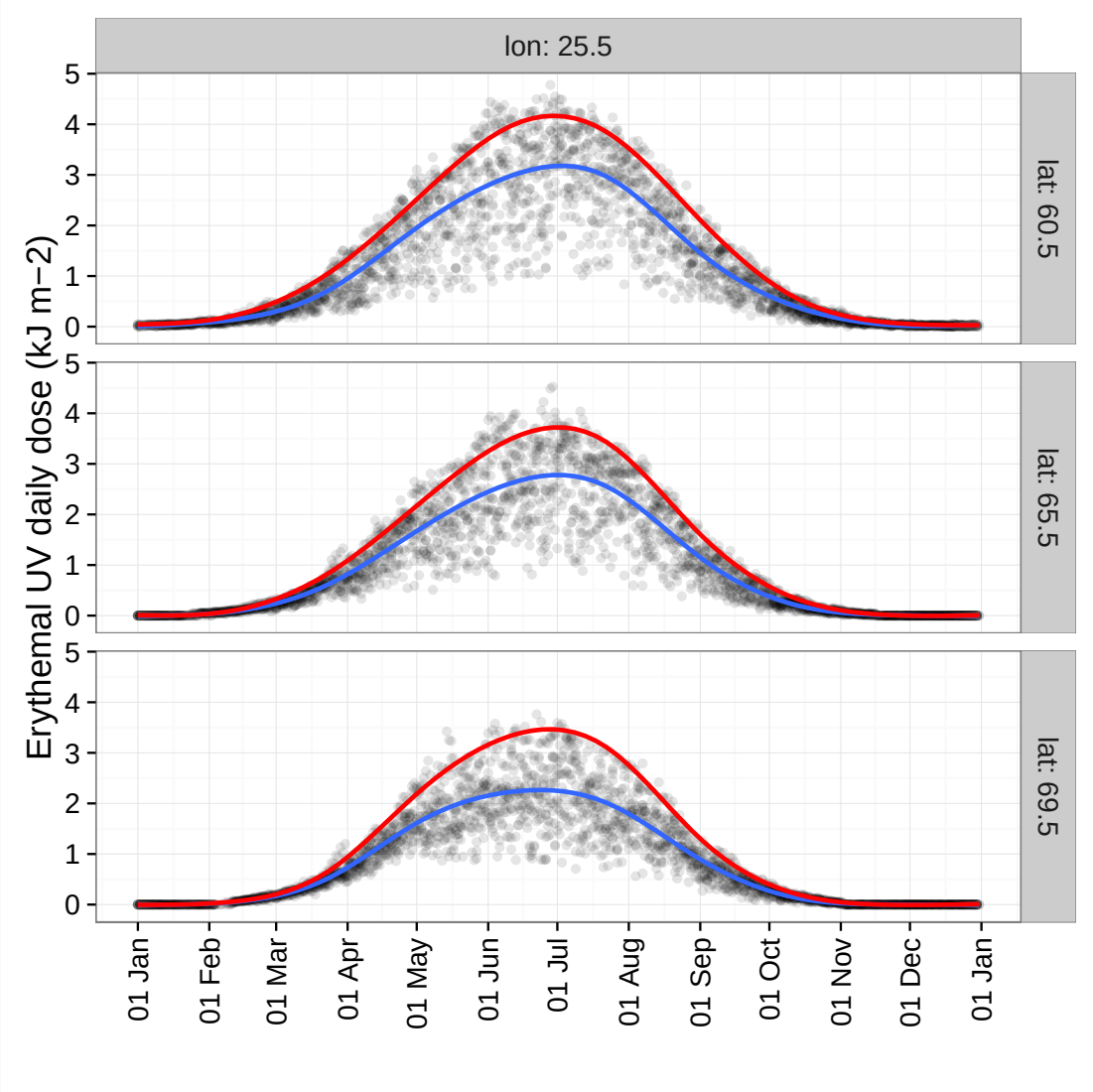
(P. J. Aphalo, A. Lindfors, unpublished)

Global radiation and its variability: 2004–2014



(P. J. Aphalo, A. Lindfors, unpublished)

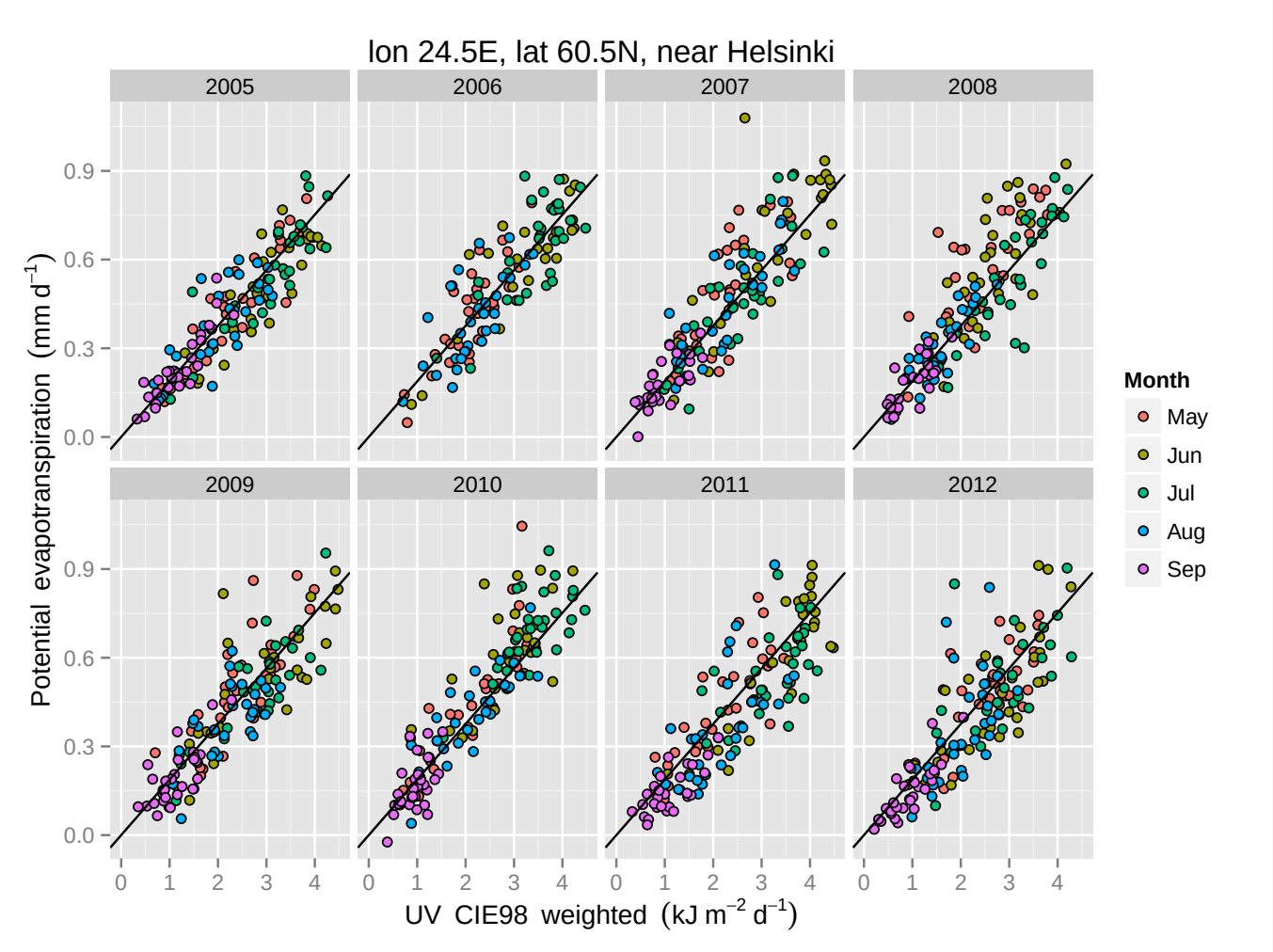
UV radiation and its variability: 2004–2014



(P. J. Aphalo, A. Lindfors, unpublished)

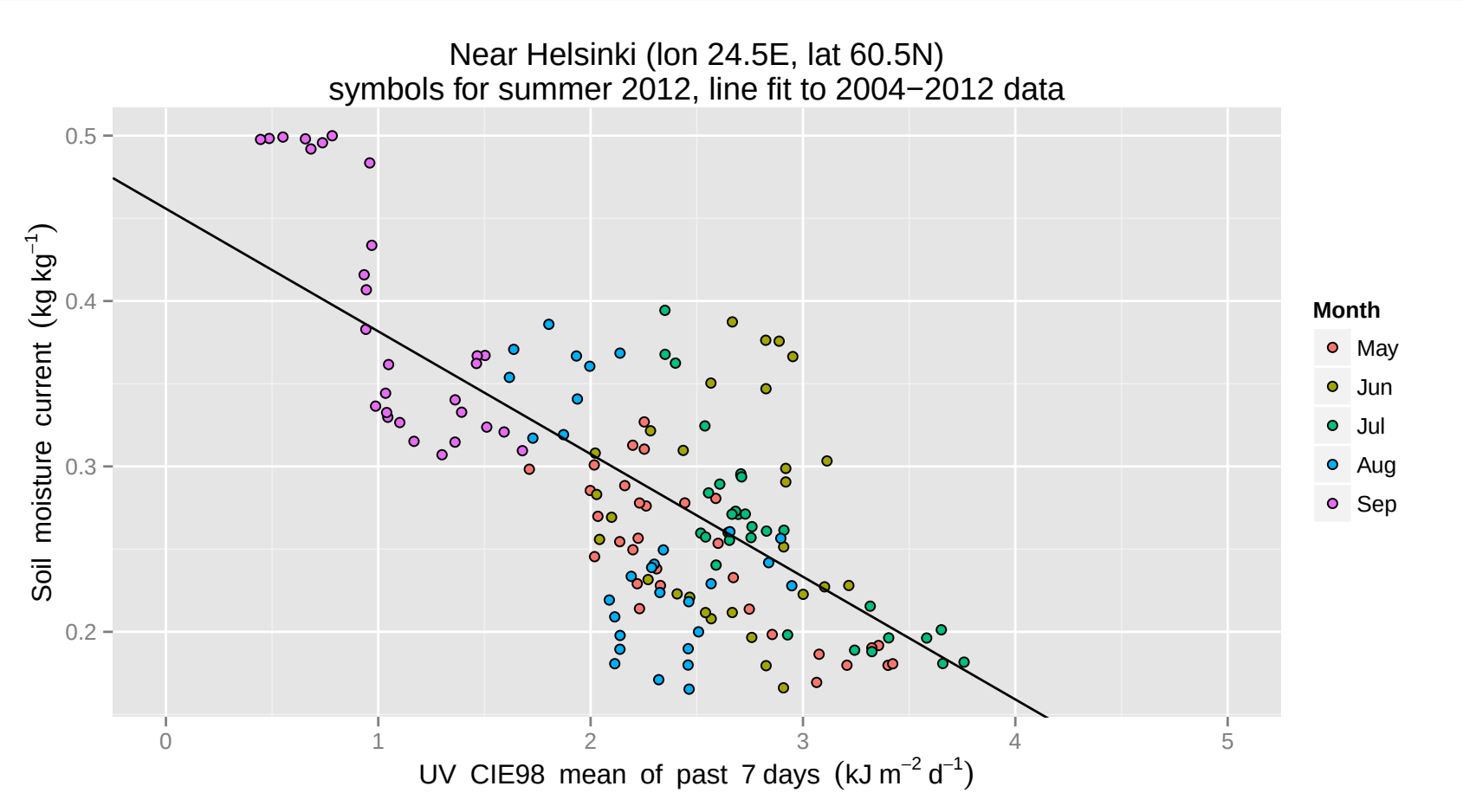
Available evidence for UVB and drought

Is there an environmental correlation? Yes



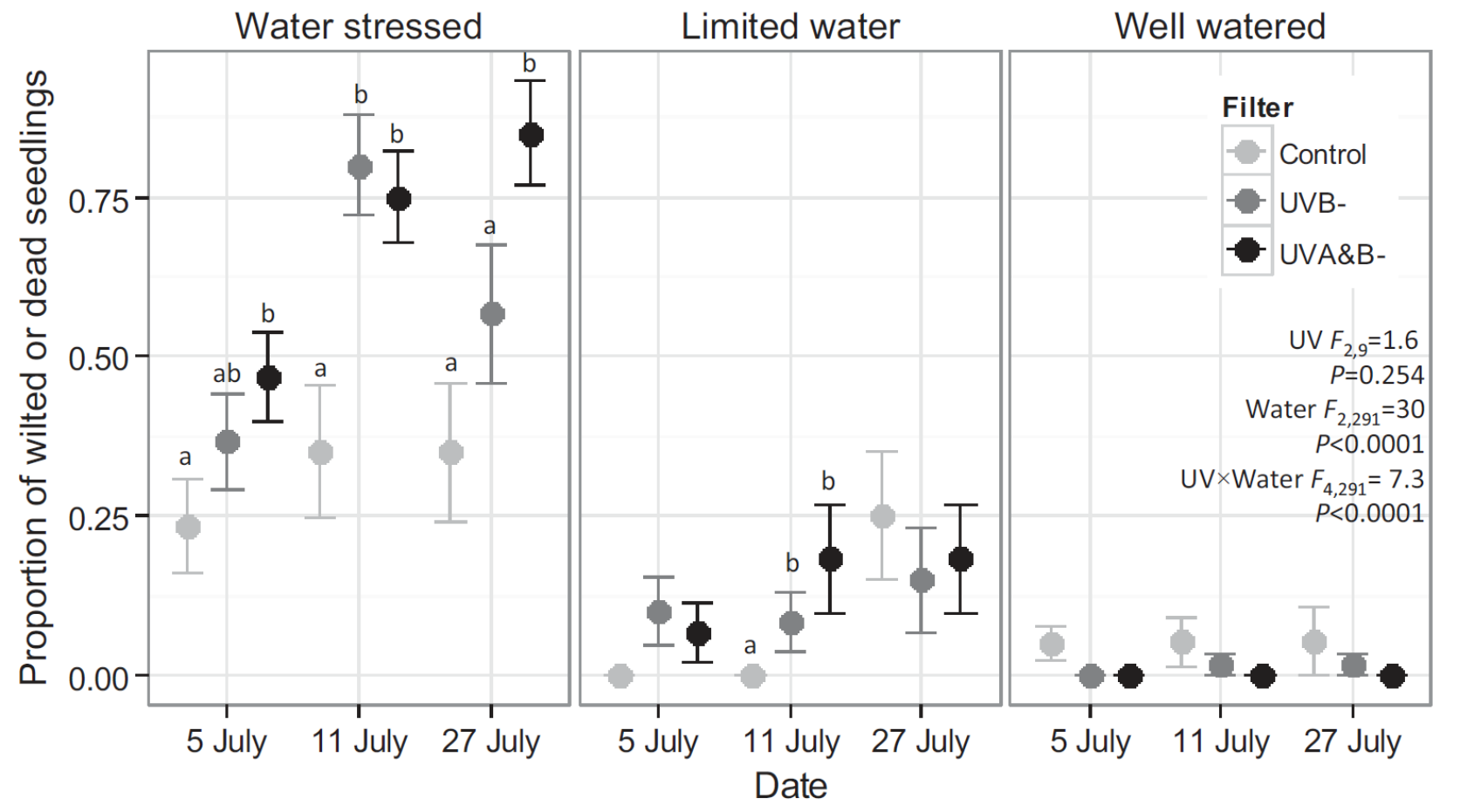
(P. J. Aphalo, A. Lindfors, unpublished)

Is there an environmental correlation? Yes



(P. J. Aphalo, A. Lindfors, unpublished)

Can exposure to UV-B trigger drought-acclimation? Yes



(Robson et al. 2014)

Preemptive acclimation: implications

Take home message from our research on UV

If our hypothesis holds for a range of species then there would be much to rethink:

- reduced growth under UV-B exposure could improve fitness instead of being deleterious,
- phenotyping for drought tolerance of dryland crops in the absence of UV-B could lead to little progress,
- what should we do with field crops under irrigation: do we need to breed out some of the UVB responses?,
- what about rain shelter experiments: should we supplement with UVB?
- What about climate change: should we acknowledge that changes in rainfall will correlate with changes in UVB?

Overall take home message

- If we use a higher level abstraction...
- ...we can more easily see the parallels between different anticipatory responses...
- ...and their commonalities, in the spirit of the general systems theory.
- Use more consistent research approaches.
- More easily apply what we already know or will learn in the future about responses like the annual cycle of trees, or the shade avoidance response, to “newly” discovered or hypothesized anticipatory responses.

A *caveat* and a question to the audience

- The model I presented is mainly dealing, at least in my examples, with relatively “normal business”, events that could take place every year to not more than a few generations apart.
- But our trees have also survived as species very exceptional extreme events.
- This has also shaped the current genotypes, so can we separate these aspects in our studies?

Acknowledgements

Members of my research group: Sari Siipola, Fang Wang, Neha Rai, Yan Yan, Cyntia Ayala.

Current collaborators: Luis O. Morales, T. Matthew Robson, Anders Lindfors, Víctor Sadras, Jorge J. Casal, Saara Hartikainen, David Israel, Mikael Brosché, Tarja Lehto, Åke Strid, Gareth Jenkins, Andreas Albert, Fred Stoddard

A new umbrella organization at our campus.

My employer.

For funding, decisions 252548, 16775.

References

- Novoplansky, A. (2016). “Future Perception in Plants”. In: *Anticipation Across Disciplines*. Springer, pp. 57–70.
- Robson, T. M., S. M. Hartikainen, and P. J. Aphalo (2014). “How does solar ultraviolet-B radiation improve drought tolerance of silver birch (*Betula pendula* Roth.) seedlings?” In: *Plant, Cell & Environment* 38, pp. 953–967. DOI: 10.1111/pce.12405.

Some connections to earlier talks

- Veikko Koski's reference to "Heisenberg's uncertainty principle" triggered some thoughts: 1) the plants perceive the state of the environment but modify it, but also 2) in experiments we modify the environment, rather drastically, to study the responses of plants.
- In the discussion after Outi Savolainen's talk about the quantitative traits and the difficulties of dealing with many alleles the discussion centred on study methods. Later in the evening I started thinking whether having so many alleles could have a function in fitness. I came out with two ideas, at least the first one not original at all: 1) a smooth "continuous" range of possible daylength thresholds is good for fine tuning during "normal business", but 2) could this also be advantageous in "extreme years" as a way of preventing the loss of any alleles from the population even if a significant part of population with a non-hardy phenotype died.

The origin of what I will present today

- BSc Agronomy with emphasis in crop breeding (Genetics + Ecology + Statistics + Meteorology)
- MSc Plant Production (Ecophysiology + Sensory photobiology + Simulation modelling + General Systems Theory)
- - Computing programming + Systems analysis
- - Electronics + Instrumentation
- PhD in “Science” (Ecophysiology + Sensory photobiology + Instrumentation + Simulation modelling)
- METLA - seedling—seedling interactions + photobiology + growth regulators
- U. Joensuu - roots + cold + UVB radiation + Instrumentation + Computer Programming + Mineral Nutrition + Secondary metabolites
- U. Jyväskylä - statistics + time series analysis + UVB + Secondary metabolites
- U. Helsinki - add Heikki, molecular biology, a few additional plant species, a pinch of metabolomics and shake well