Modelling of climate change impact on forest tree populations

Koen Kramer
Alterra

Evoltree Summer School

Zvolen, September 10-14, 2007

Structure of the presentation

Modelling the annual cycle

- fixed sequence development
- triggered development
- fluctuating development

Examples:

- testing of the model
- impacts of climate change on duration of growing season and frost hardiness, consequences for growth
- adaptation & selection on phenological parameters
- genetic consequences

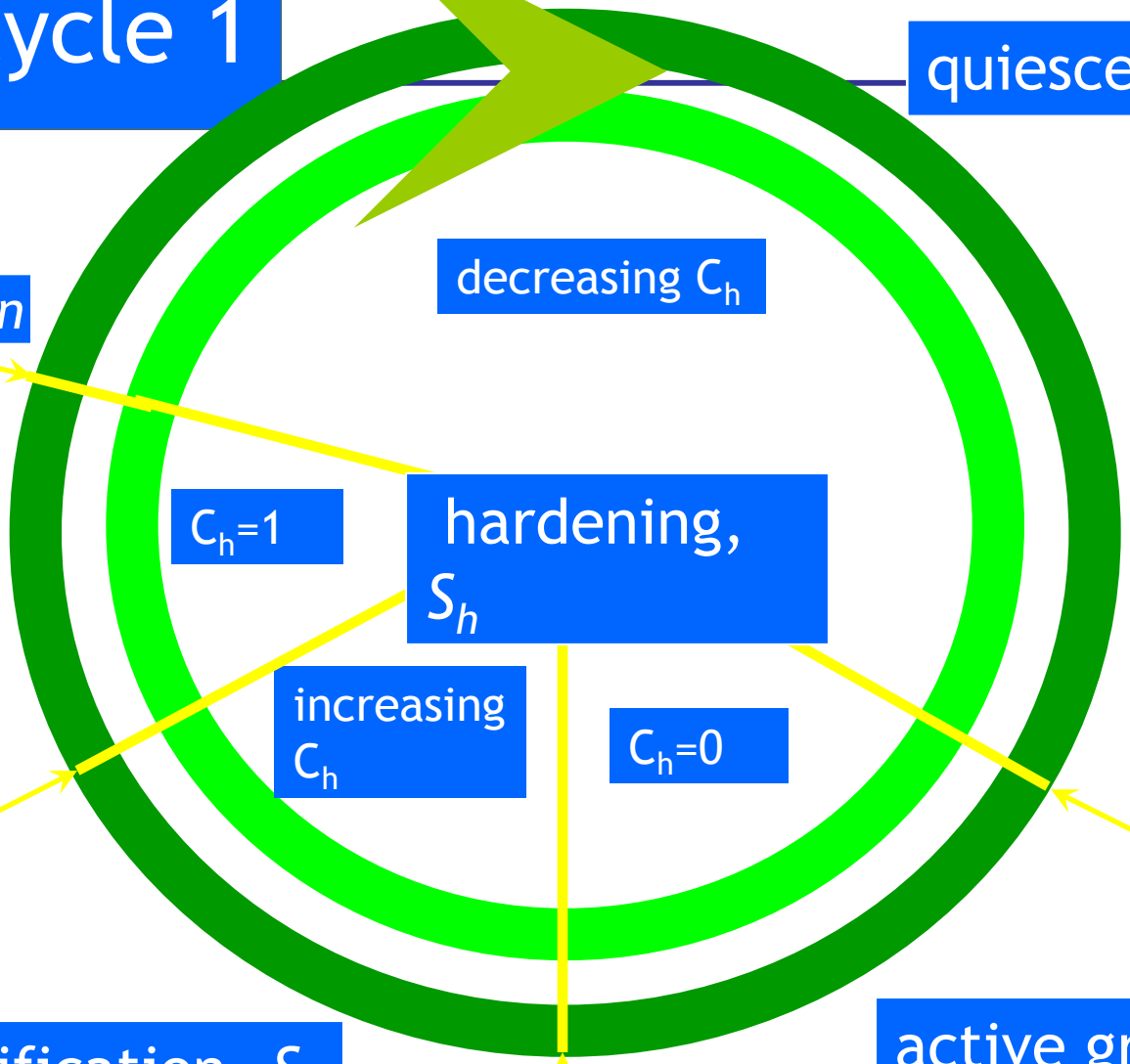
fixed sequence development

- driving force of development: environmental conditions affecting rate of development, not fluctuations of environmental conditions
- irreversible, no ‘backward’ development possible
- => seasonal development without seasonality in environmental factors
- role of genetic factors: influence how the rate of development responds to environmental factors
- triggered development: special case of fluctuating development, binary response to environmental condition
- e.g.: bud burst; leaf fall

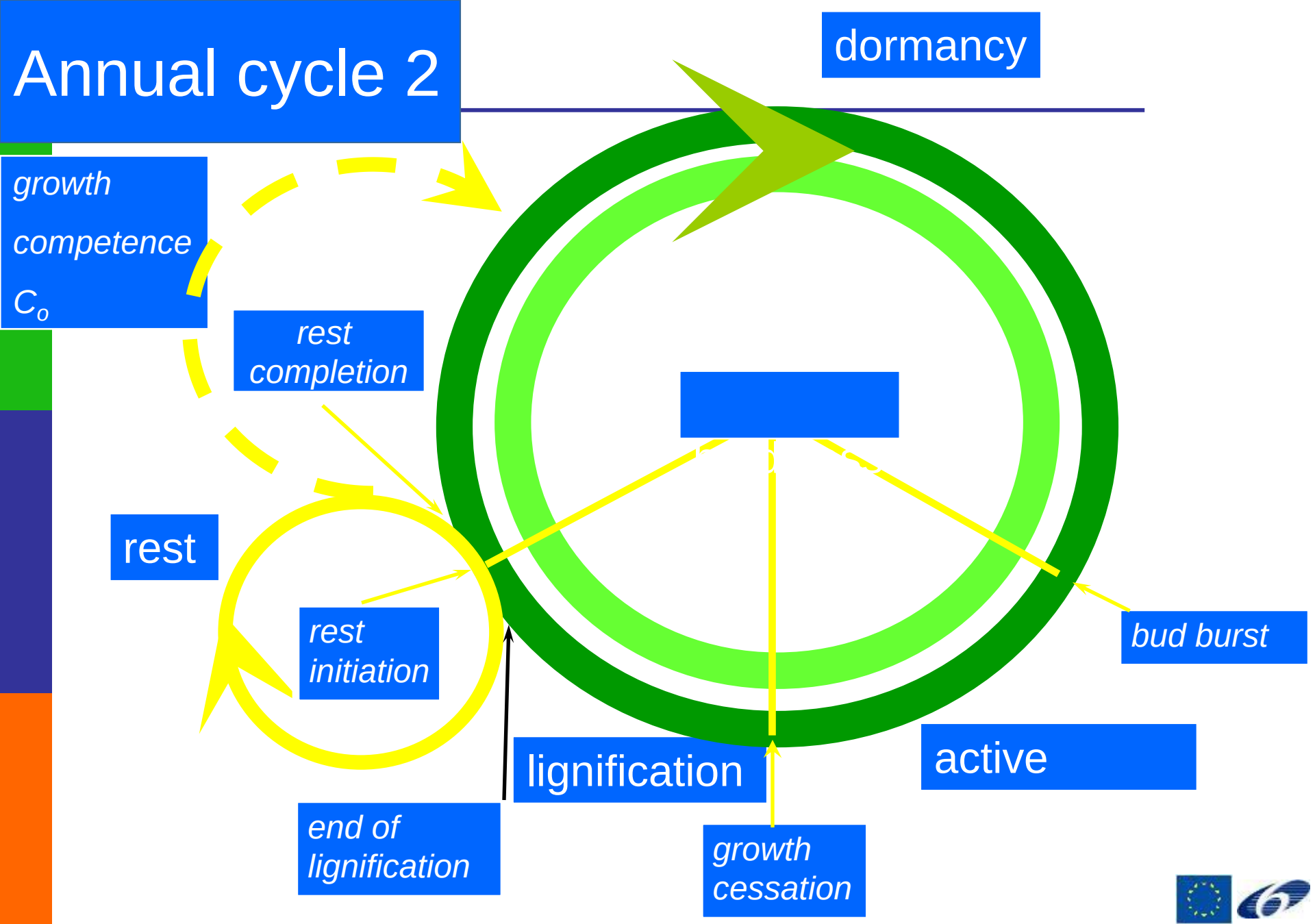
fluctuating development

- driving force of development: fluctuations in environmental conditions. No development in constant environment
- reversible: ‘backward development’ possible
- => seasonal development only if seasonality in environmental factors
- stationary state: specific target state of development under specific set on environmental conditions
- role of genetic factors: on stationary state and rate at which stationary state is attained
- e.g. frost hardiness; photosynthetic capacity

Annual cycle 1



Annual cycle 2

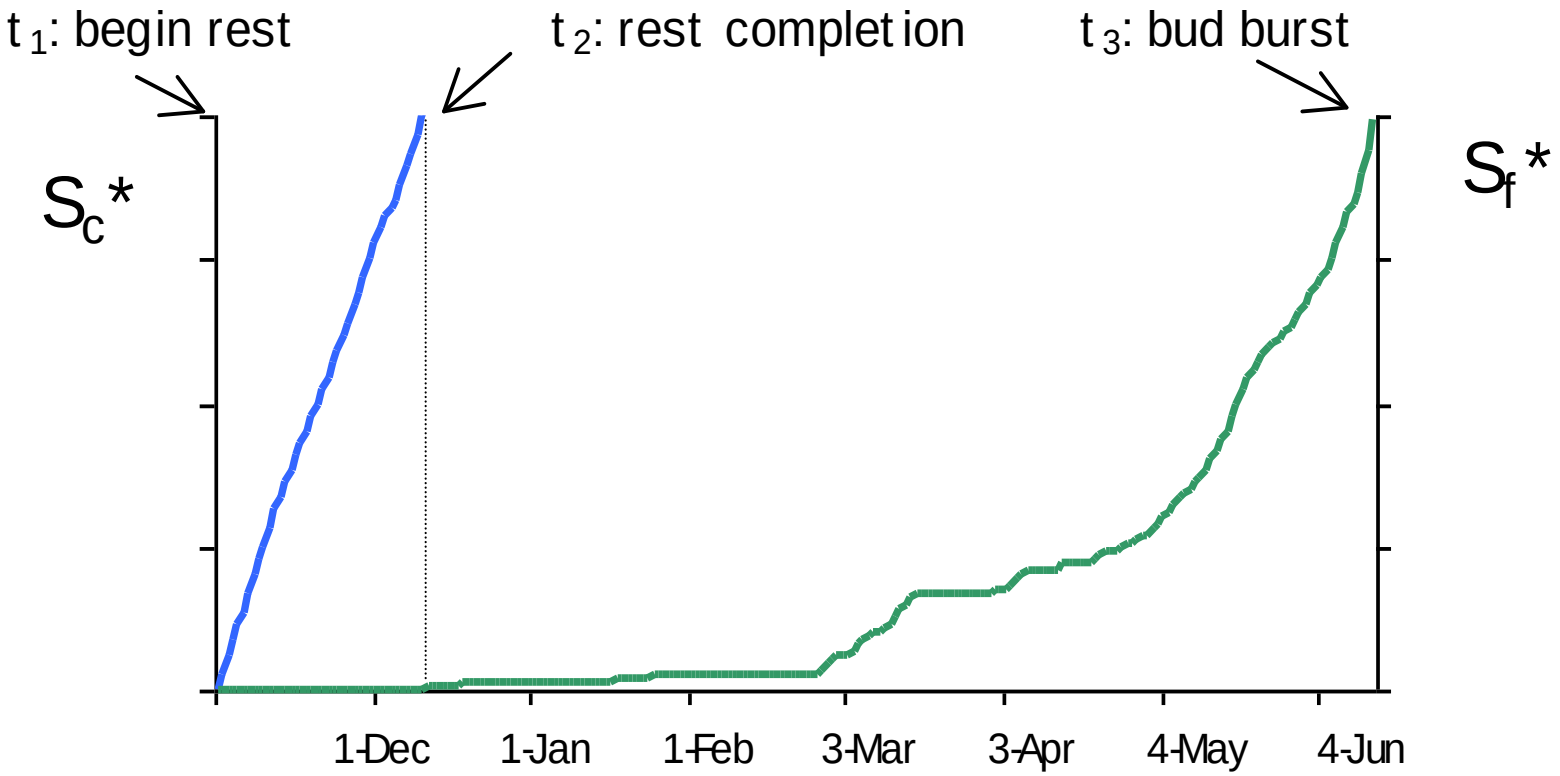


Fixed sequence development

$$S_c = \sum_{t_1}^{t_2} R_c(T); \quad t_2 : S_c = S_c^*$$

$$S_f = \sum_{t_2}^{t_3} R_f(T); \quad t_3 : S_f = S_f^*$$

Fixed sequence development



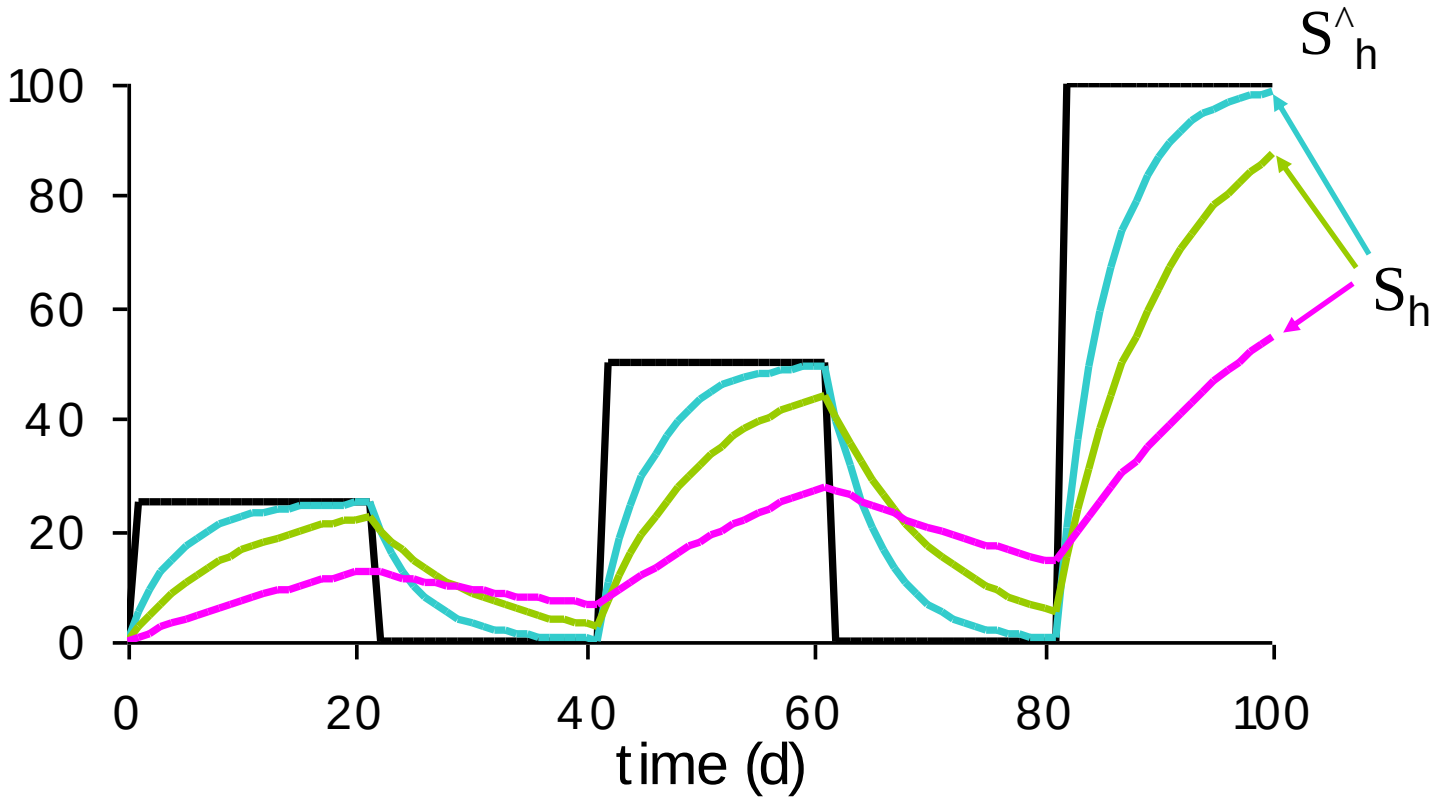
Fluctuating development

$$\hat{S}_h = \hat{S}_{h,min} + \hat{\Delta S}_h(T) + \hat{\Delta S}_h(P)$$

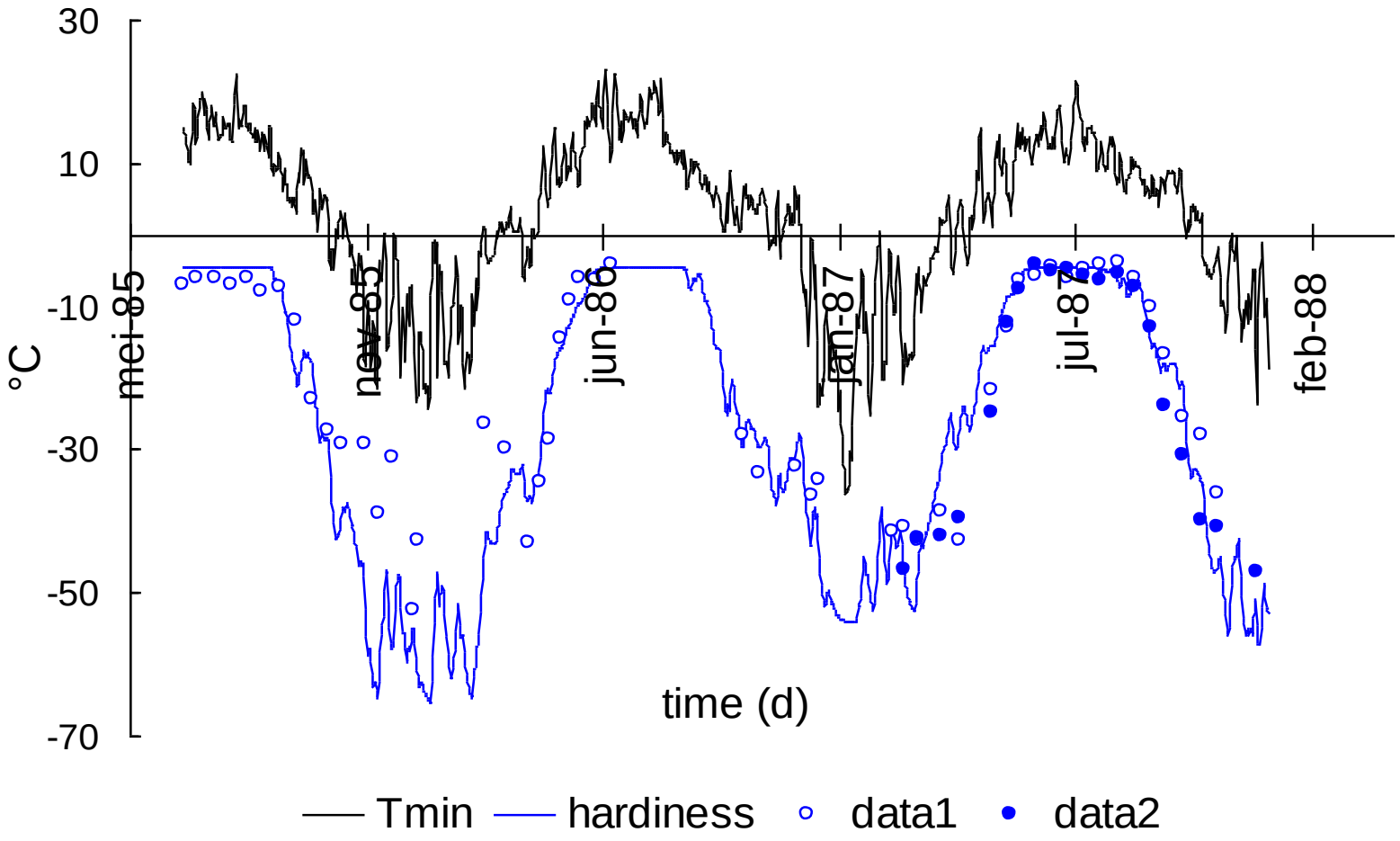
$$R_h = C_h(S_f) \cdot \frac{1}{\tau} \cdot \left(\hat{S}_h - S_h\right)$$

$$S_h = \sum R_h$$

Fluctuating development

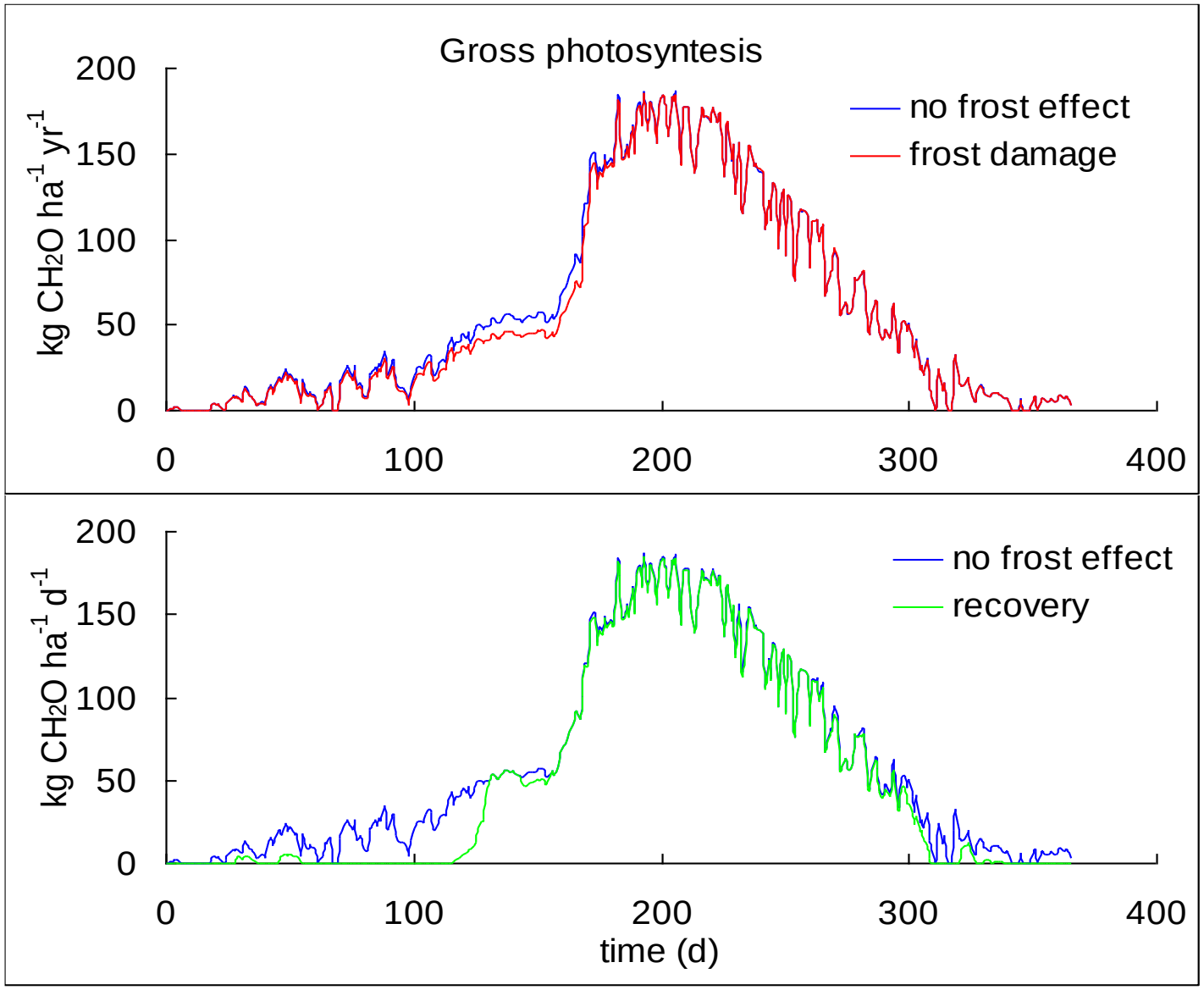


Testing: frost hardiness (S_h)

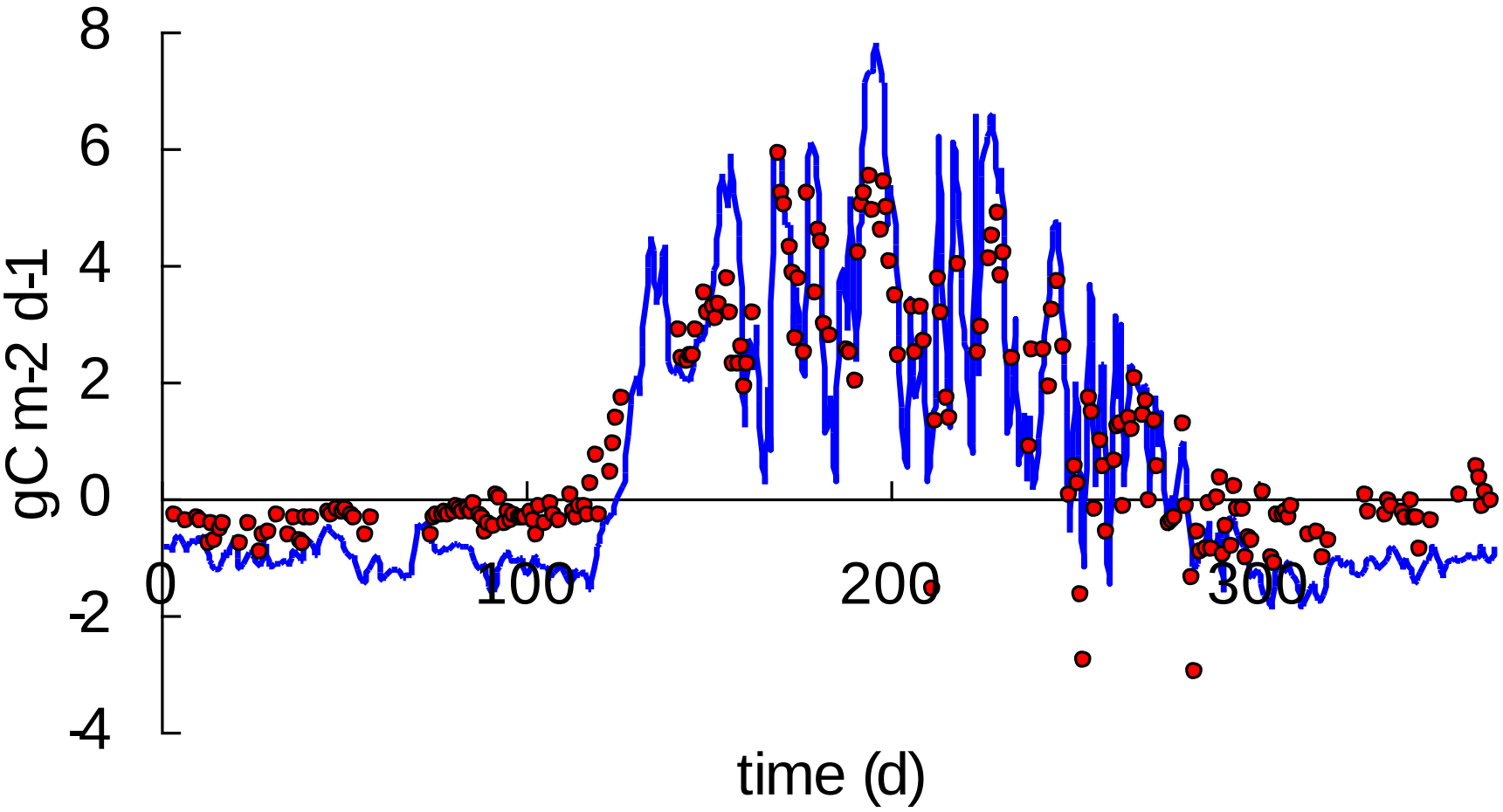


data: I. Leinonen

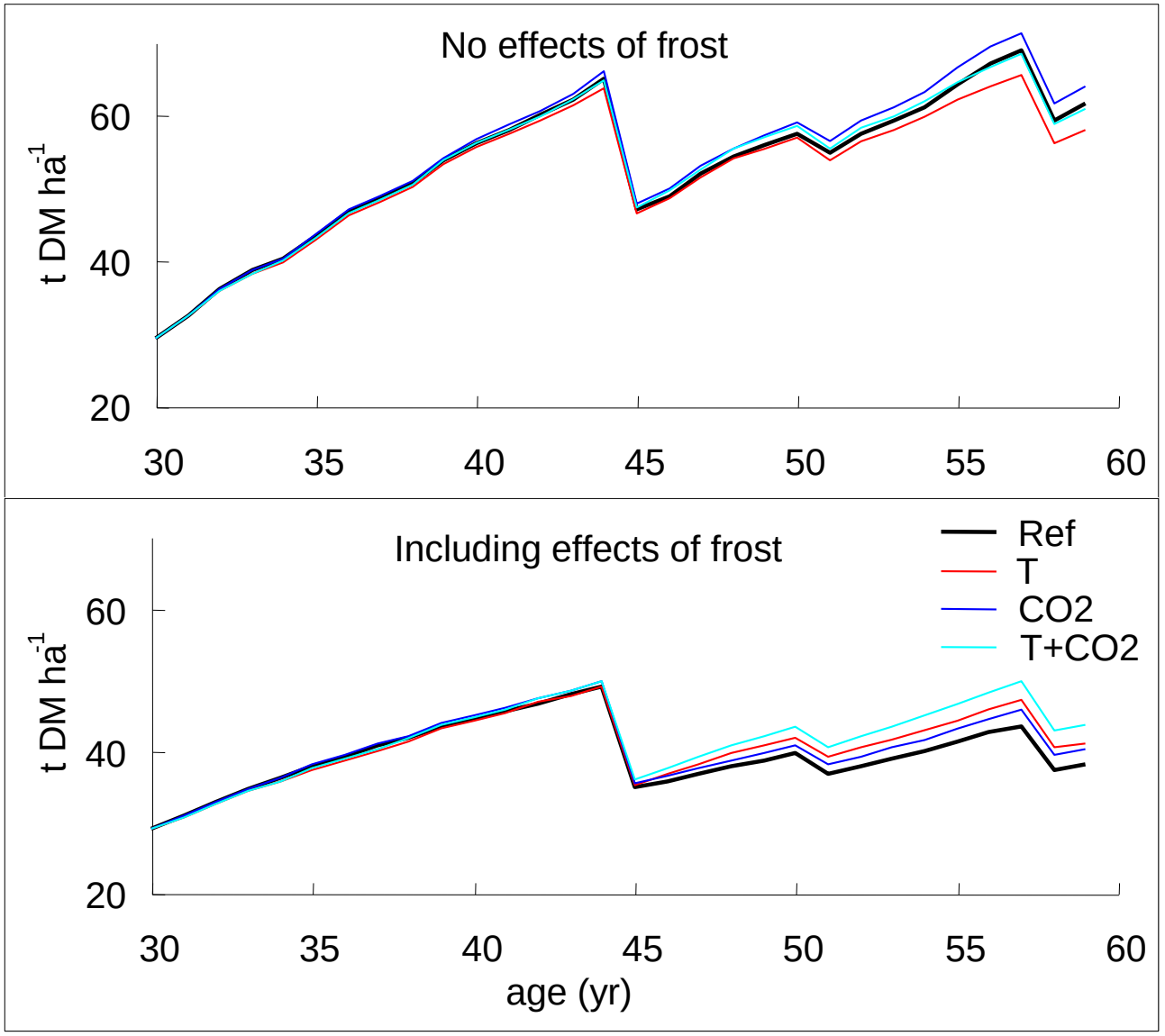
Short-term effect of needle damage and recovery of photosynthetic capacity



Testing: model x flux data



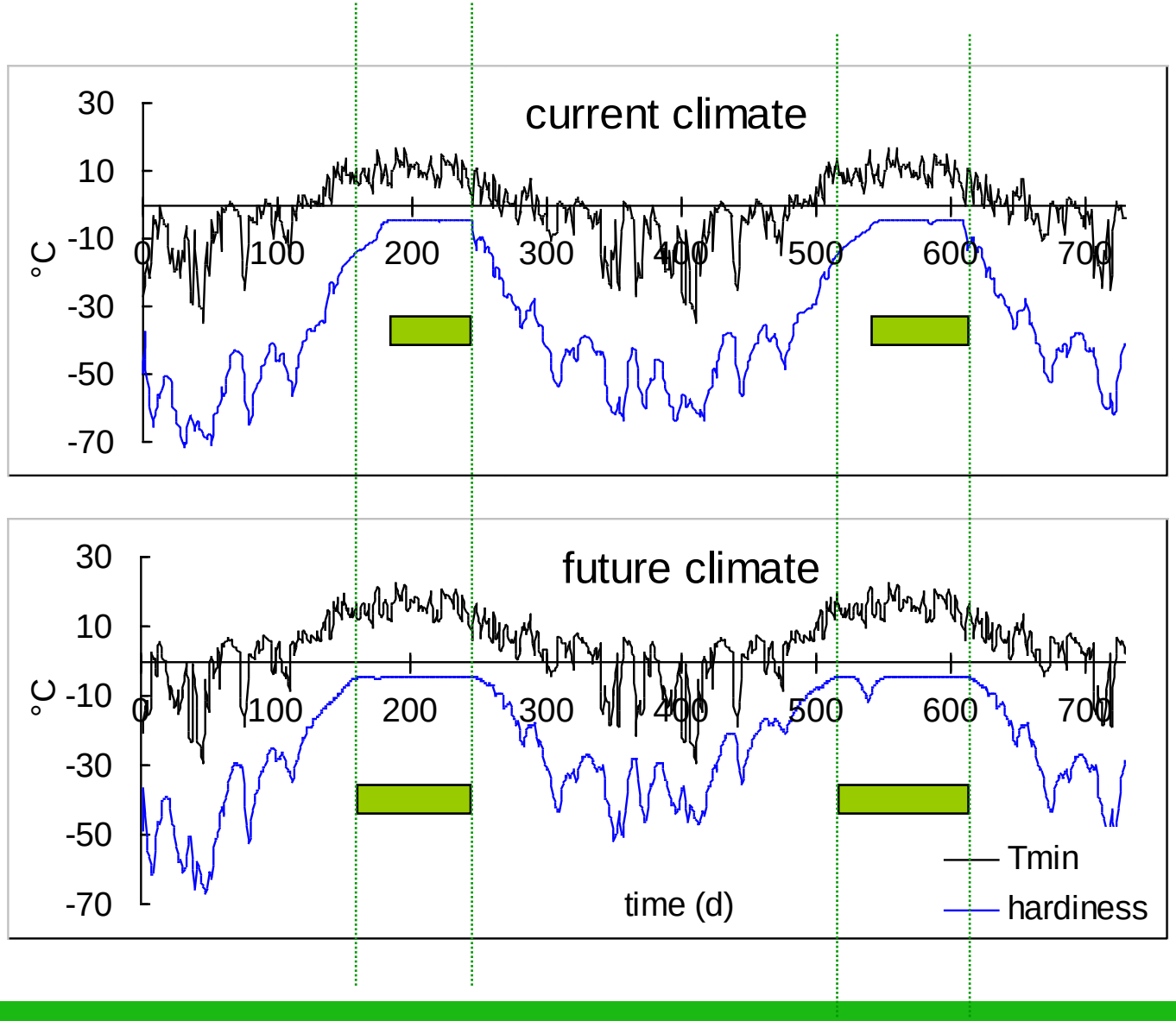
Long-term effect of frost on stand productivity (Pinus sylvestris)



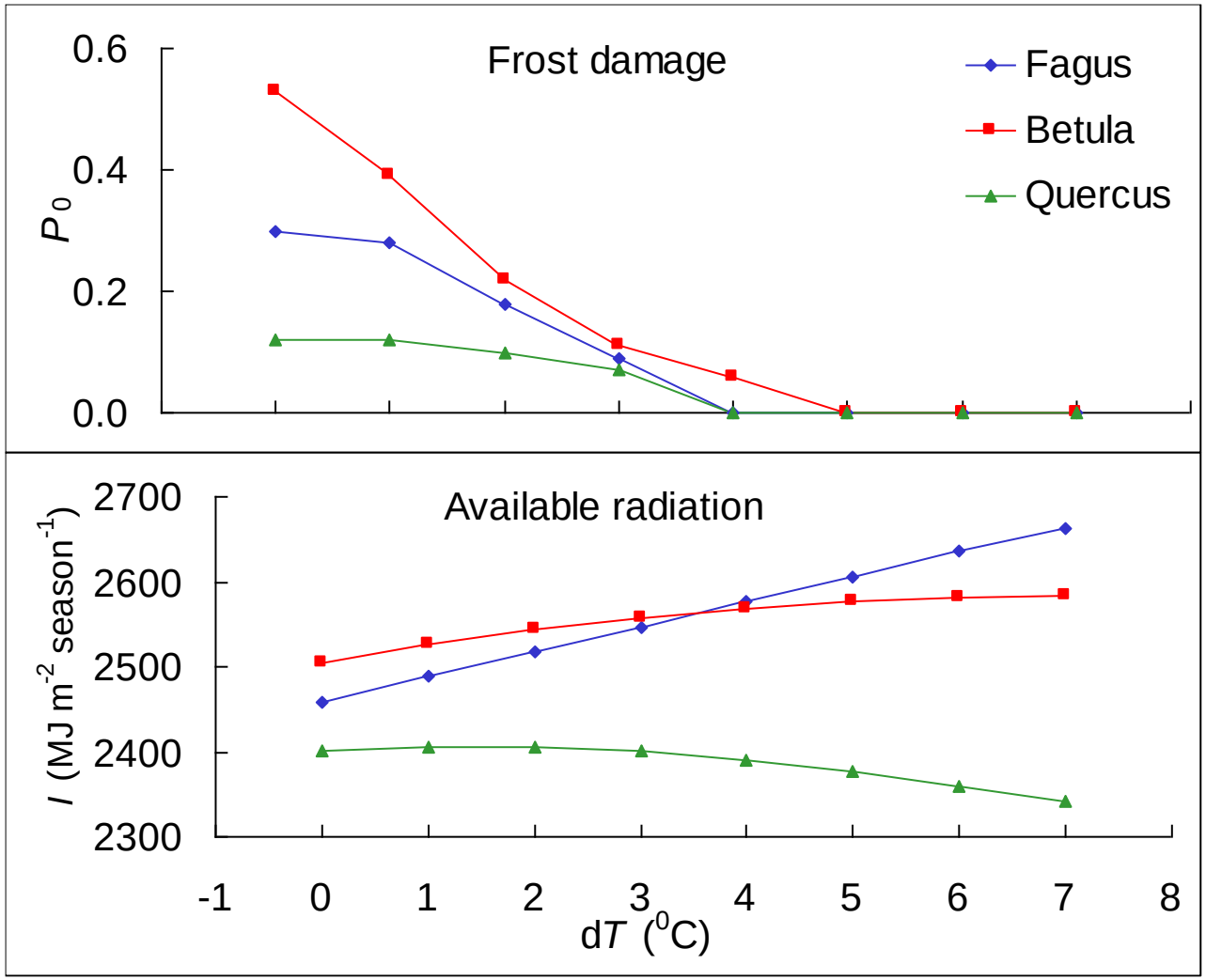
Examples of impacts of climate change

- duration of the growing season & frost hardiness
- probability of frost damage & available radiation during growing season

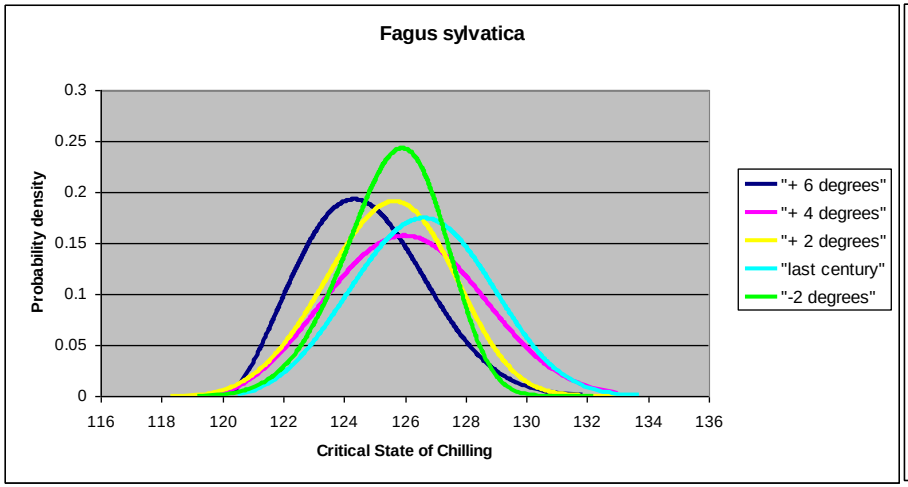
Growing season & frost hardiness

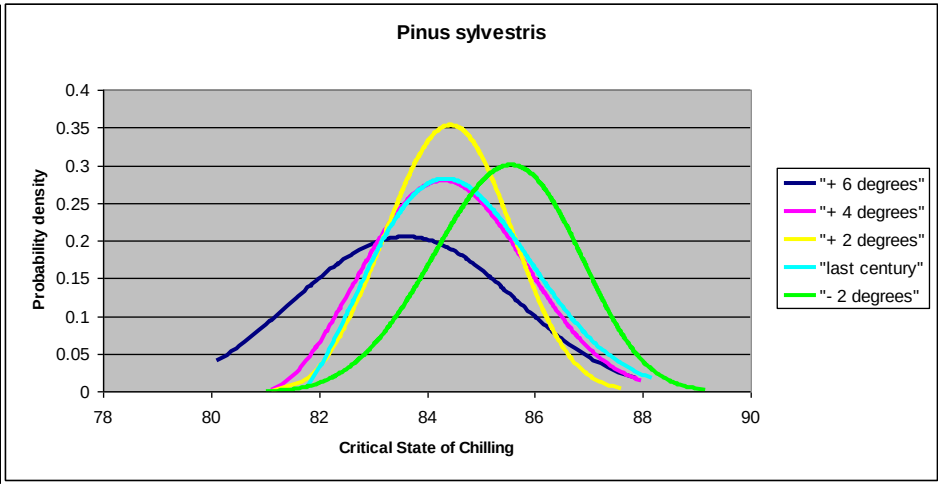


Frost damage around budburst and available radiation during growing season



ForGEM: Selection & adaptation on S_c^*





Model for timing of budburst:

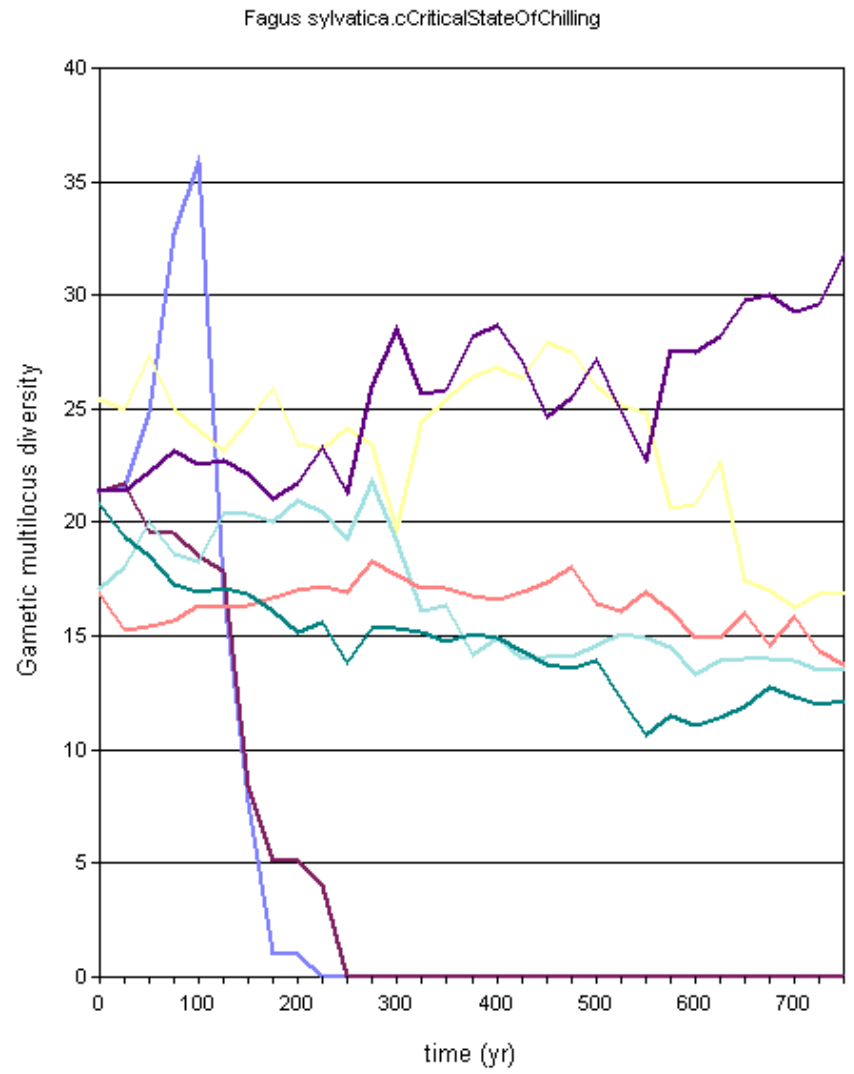
- needs first a period of chilling till total temperature sum reaches critical value
- needs after that a period of forcing till total temperature sum reaches critical value

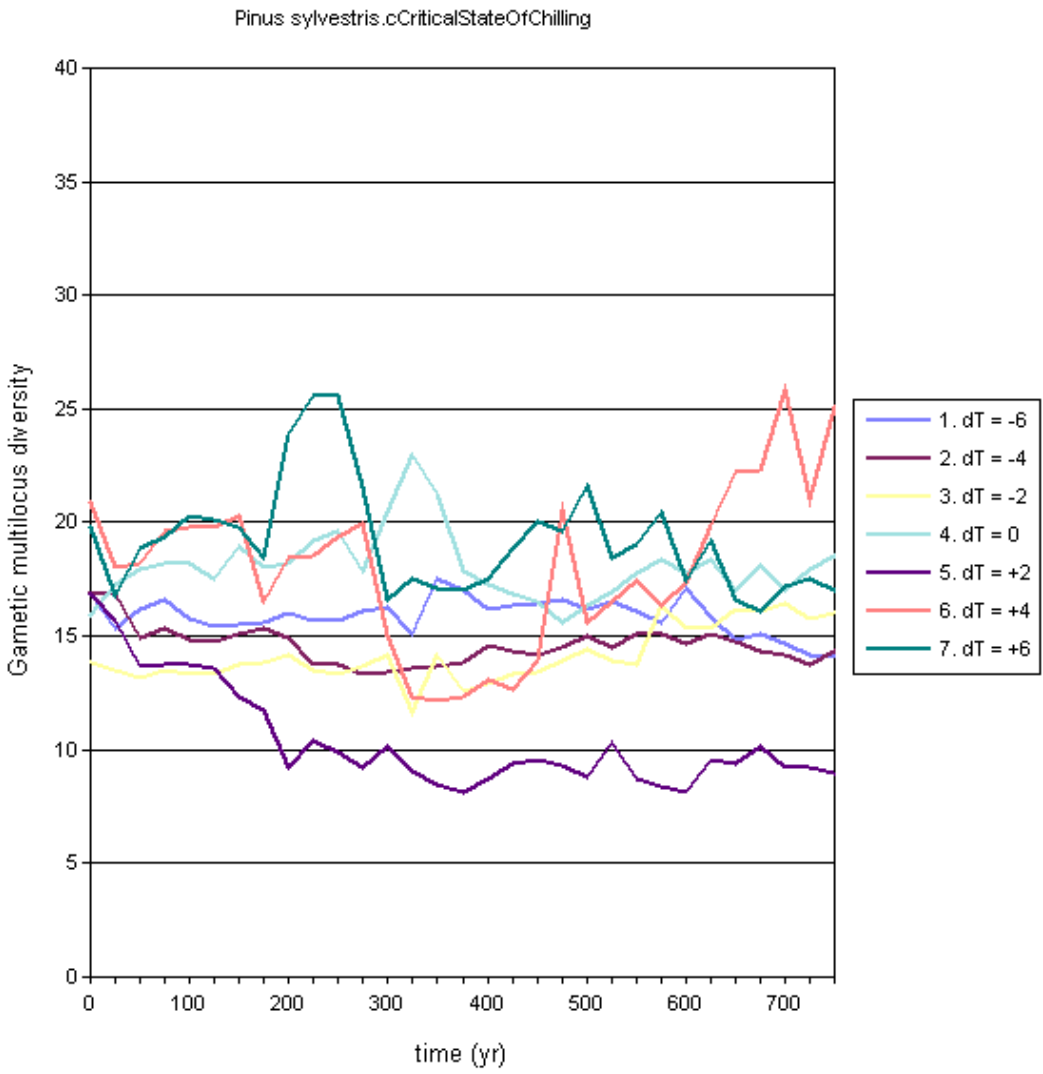
Decrease in critical value for chilling:

- risk of freezing
- longer growth season
- start of flowering is coupled with budburst could lead to genetic drift

only 1 realization!

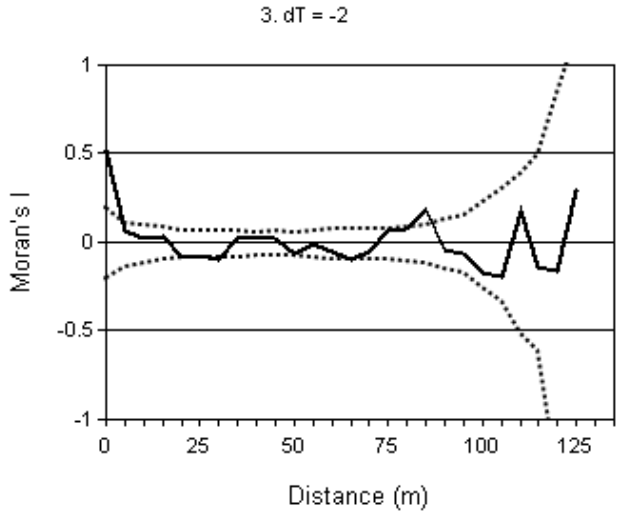
Genetic diversity of Schl* for budburst of F. sylvatica at t=500yr. Without management.

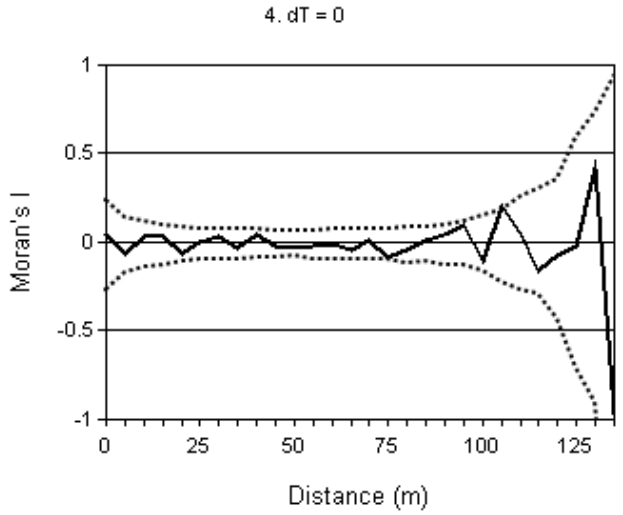


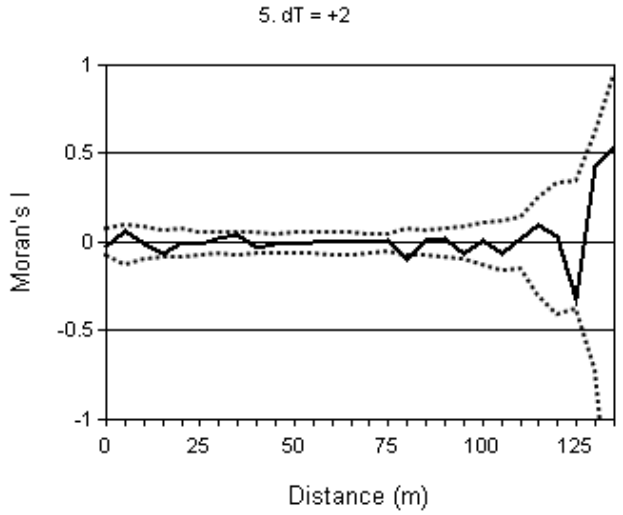


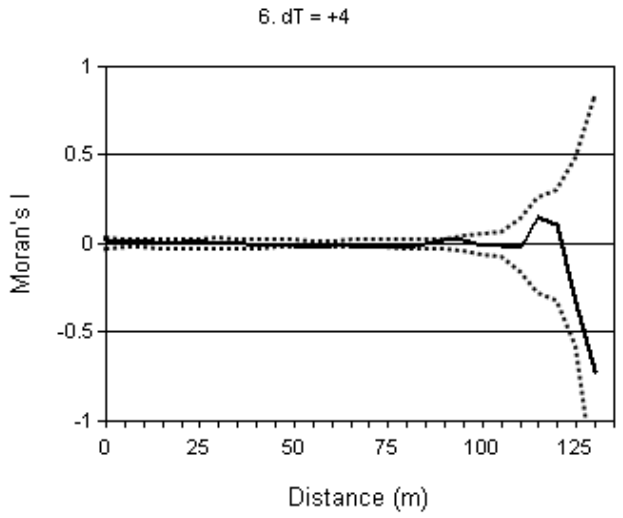
only 1 realization!

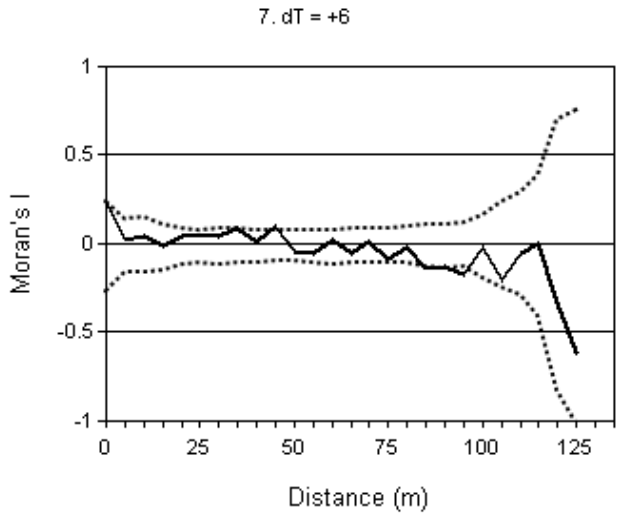
Spatial genetic structure of Schl* for budburst of F. sylvatica at t=500yr. Without management.





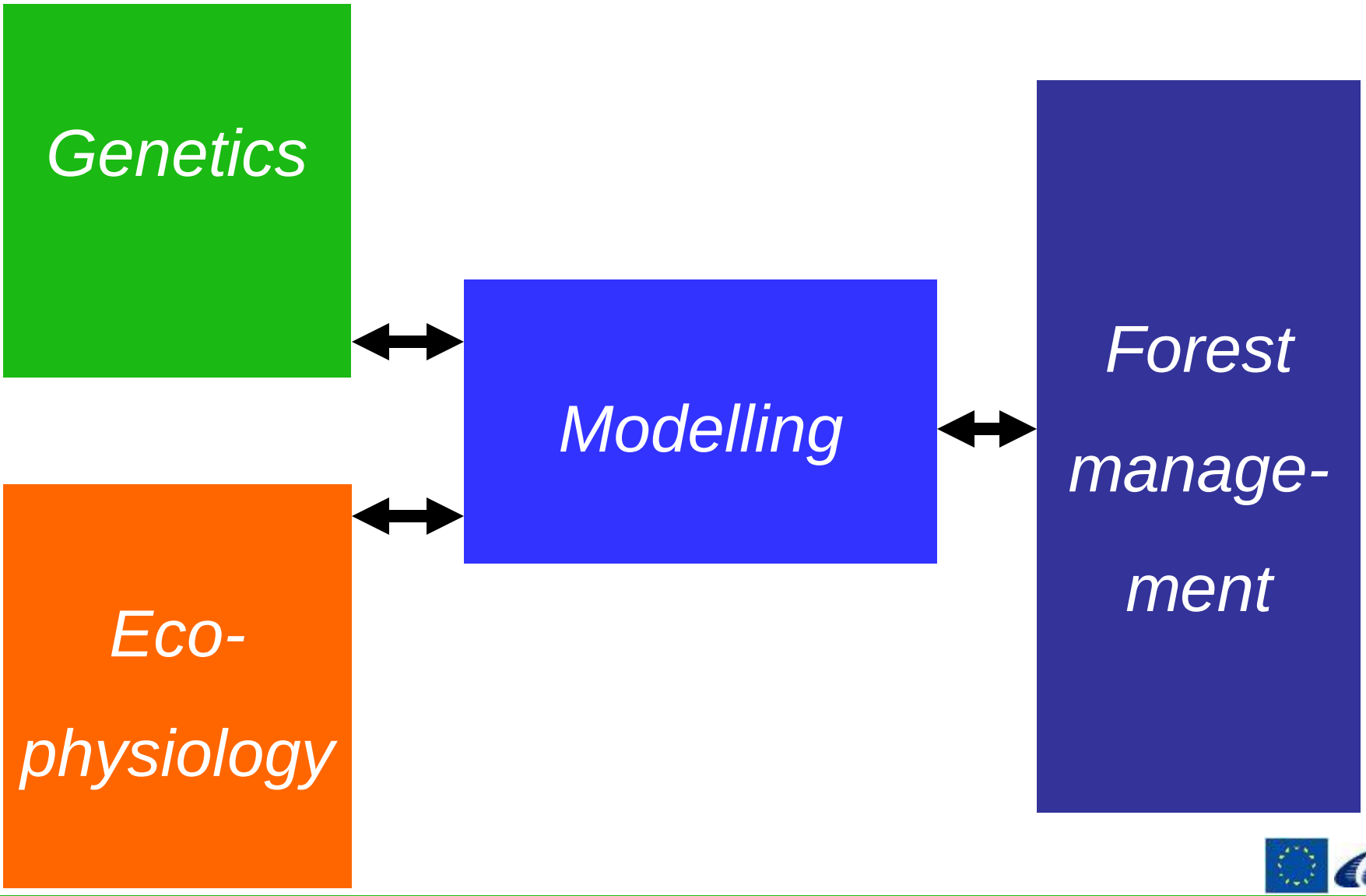






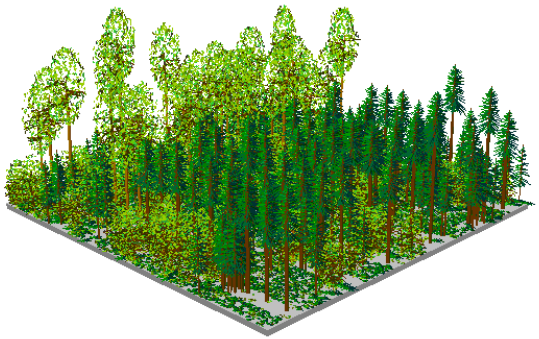
only 1 realization!

Modelling ambition



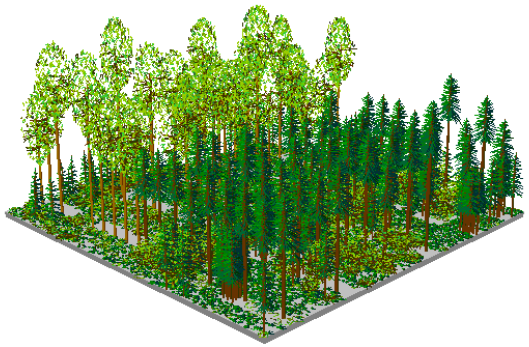
Past century

ISMB-ECCB after Time: 50 year



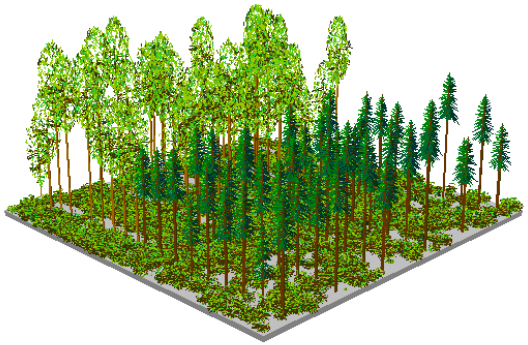
-2°

ISMB-ECCB after Time: 50 year



+6°

ISMB-ECCB after Time: 10 year



Koen.Kramer@wur.nl

Bert.vanderWerf@wur.nl