

# Resource-use description in physiology-based models

16.06.2011

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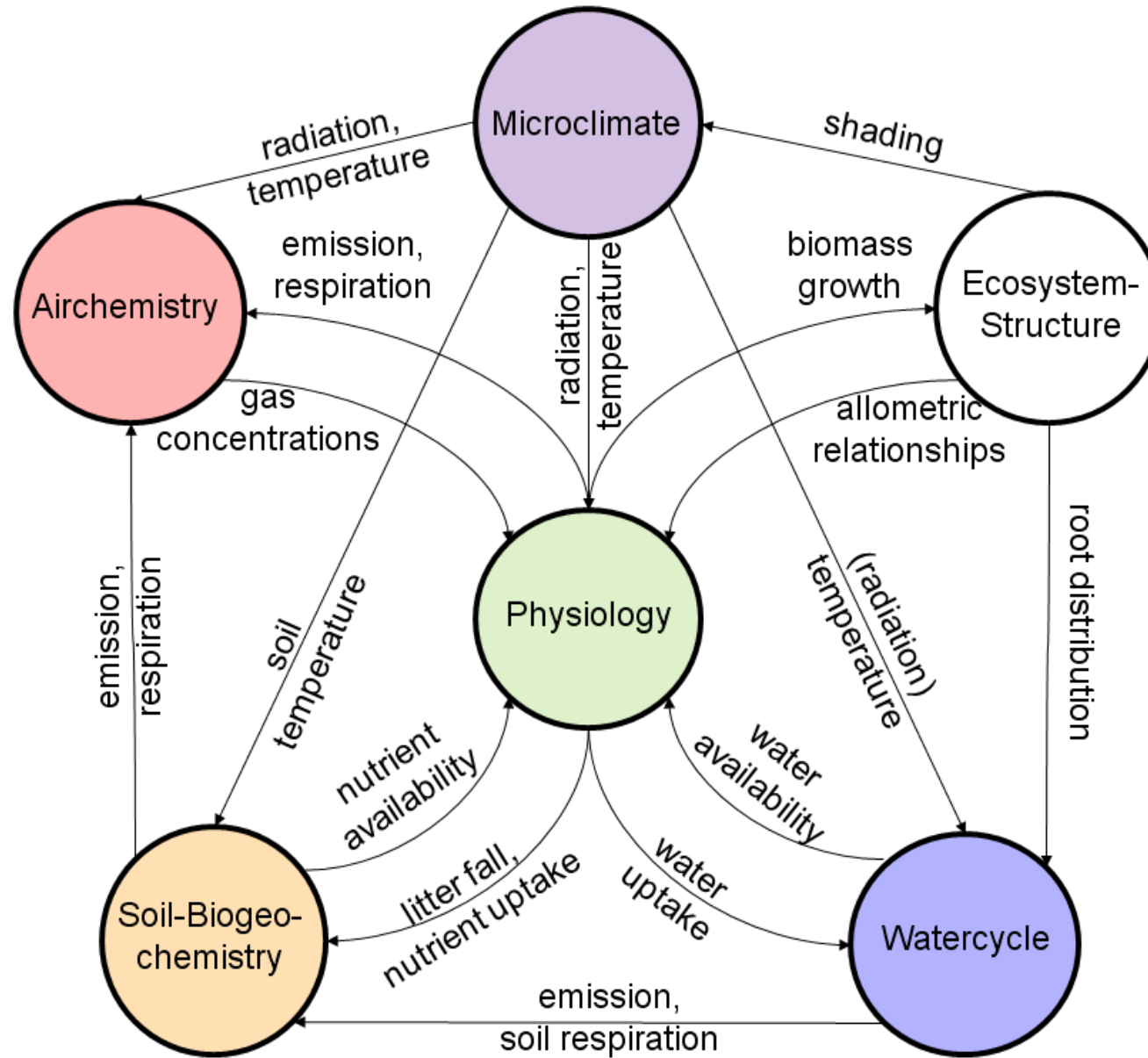
# Addressing resource-related(?) problems with a physiology-based ecosystem model

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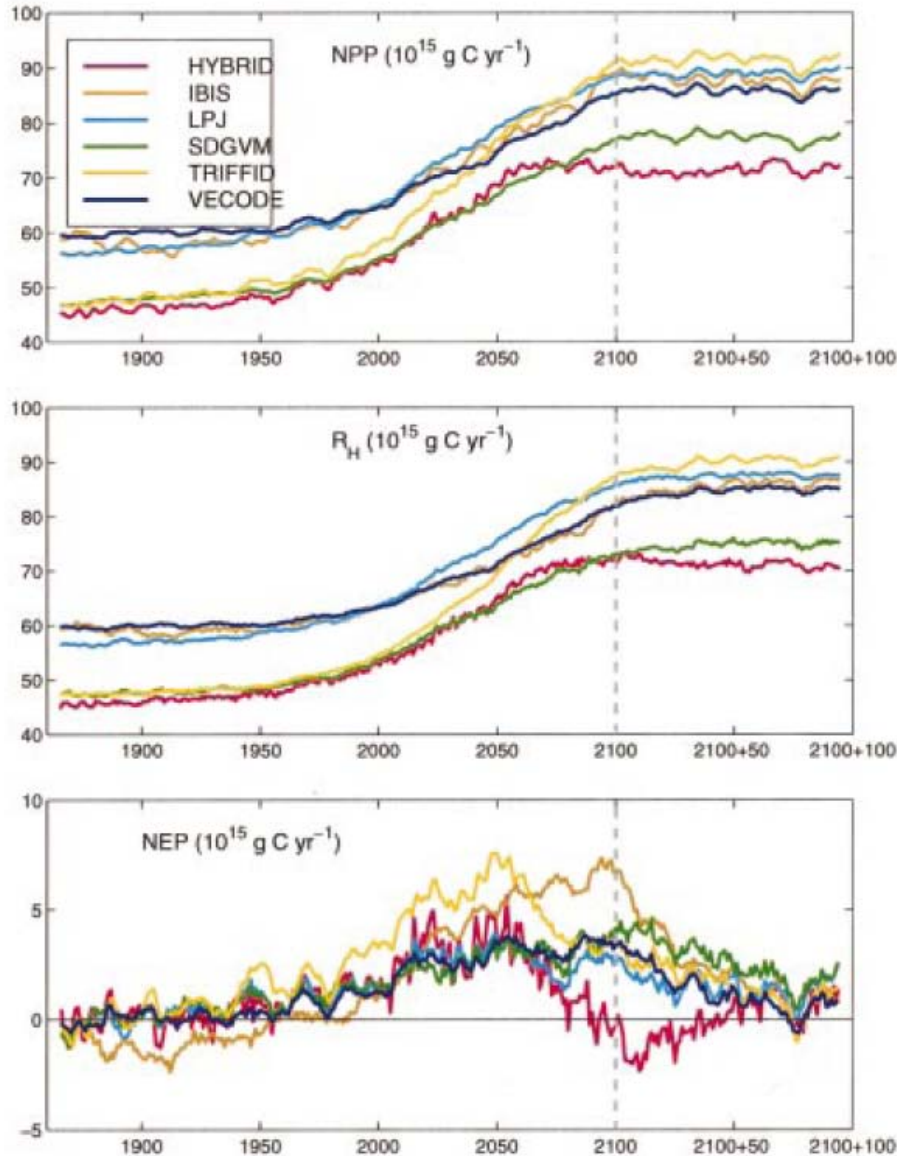
# Definition: "physiology-based ecosystem model"



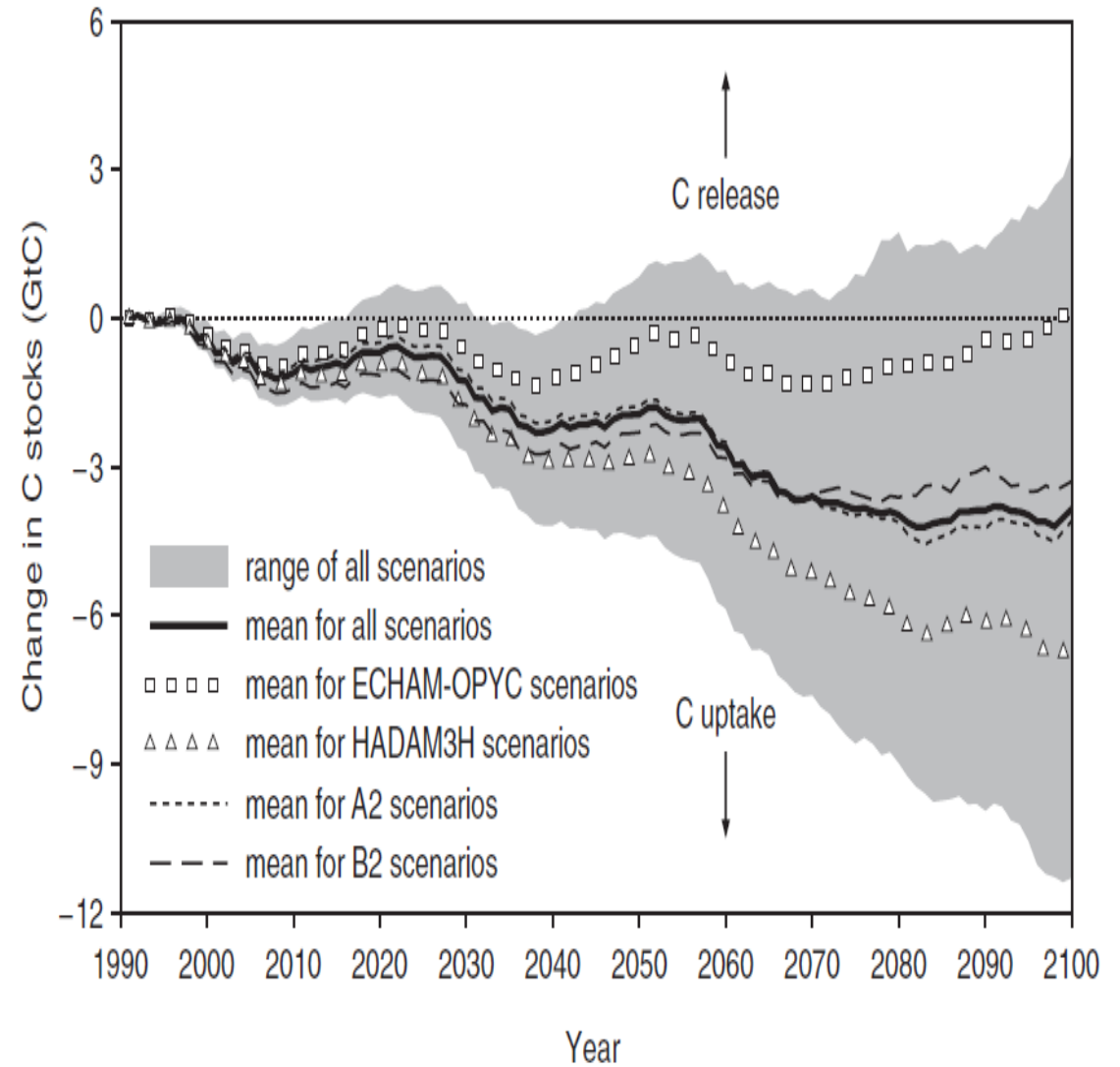
Resource  
-Uptake  
-Distribution  
-Release



# Definition: "problems"



(Cramer et al. 2001)



(Morales et al. 2005)

# Definition: "problems"

## Requirements:

1. Changes within the soil  
(microbes, storage changes)
2. Physiological adjustments  
(seasonal, inter-annual)
3. Interaction with other individuals  
(between species)
4. Response on disturbances



# Modular Biosphere simulation Framework (MoBiLE)

Empirical Canopy Model (ECM)

(Grote 2007, Holst et al. 2010)

Dynamic Treegrowth Model (M-TREEDYN)

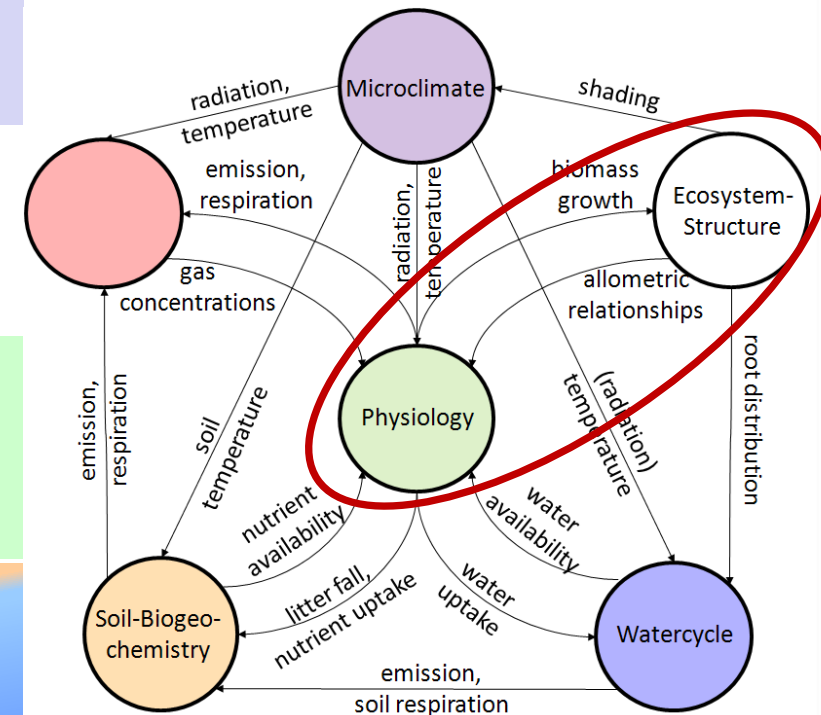
(Bossel et al. 1996, Grote et al. 2011)

Physiological Simulation Model (PSIM)

(Grote et al. 2009, 2010)

DeNitrification-DeComposition (DNDC)

(Li et al. 1992, 2000)

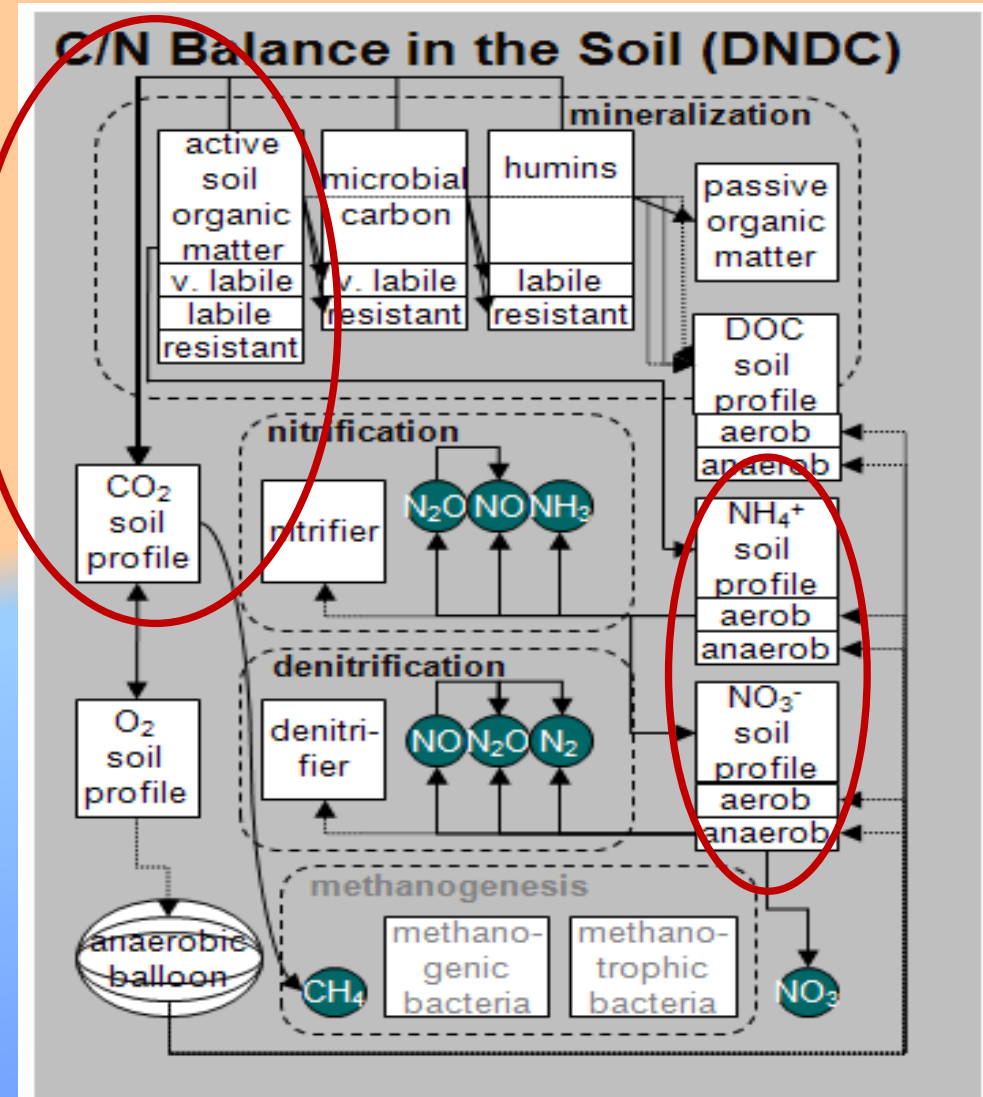


→ MoBiLE-PSIM

# Modular Simulation Framework (MoBiLE)

## DeNitrification-DeComposition (DNDC)

(Li et al. 1992, 2000)





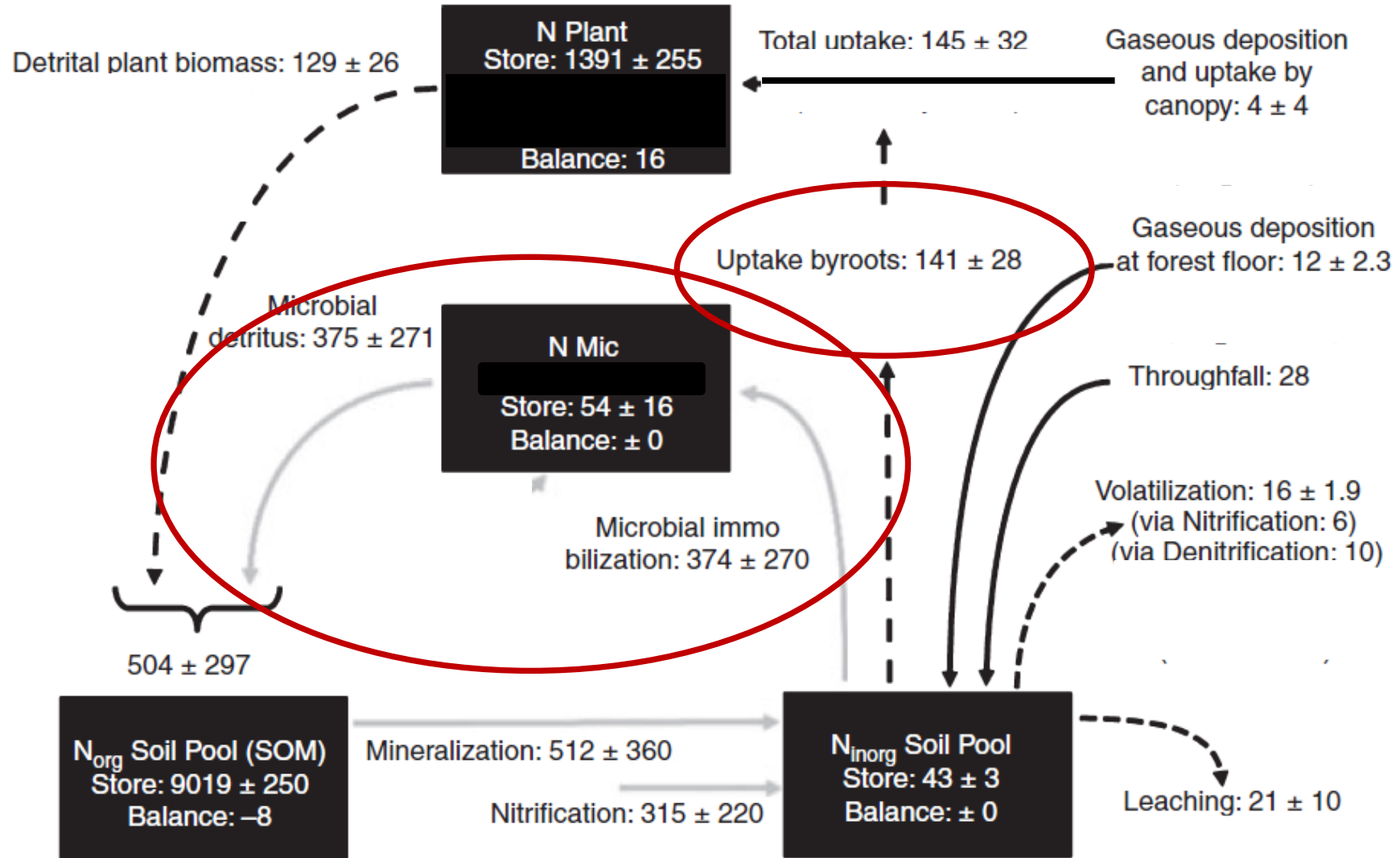
# Example: Interaction with soil → Högwald/spruce





# Example: Interaction with soil → Höglwald/spruce

## 3. Results

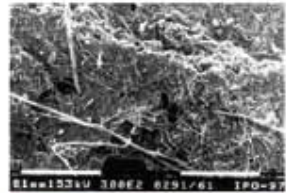


Kreutzer et al. 2009 (slightly modified, all values in kg N ha<sup>-1</sup> resp. kg N ha<sup>-1</sup> a<sup>-1</sup>)

# Mycorrhiza



Extraradical mycelium provides increased surface area for nutrient uptake, bridges nutrient depletion zones.



Ectomycorrhizal fungal hyphae colonising microsites in a rock surface

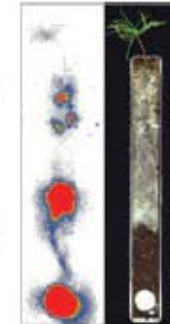


Solubilisation of tri-calcium phosphate by ectomycorrhizal fungus and associated bacteria

organic acids, siderophores and other chelating agents

Mobilisation of N & P from organic polymers from microbial biomass, micro- & meso-fauna and plant litter intervention in microbial mobilisation-immobilisation cycles

degradative enzymes, antibiotics & other chemically antagonistic compounds



Electronic autoradiography showing transfer of P from saprotrophic mycelium to a pine plant via an ectomycorrhizal fungus

Synergistic, competitive or antagonistic interactions associative N fixation exudation of organic compounds at hyphal tips

Penetration of microsites

mineral nutrients

weathering & solubilisation of minerals

organic nutrients

Possible effects of mycorrhizal symbiosis

interactions with other organisms

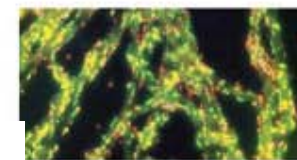
H<sup>+</sup>

Al<sup>3+</sup>

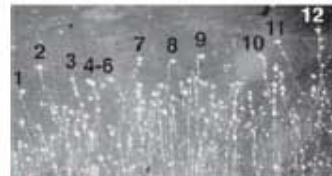
mediation of stress

Increased drought tolerance capture and restricted leachin of base cations in acidified soil chelation of toxic heavy metal and aluminium

carbon cycling



al (green) & non-vital (red) bacteria associated with the mycelium of an ectomycorrhizal fungus



Exudation of liquid drops at hyphal tips of *Suillus bovinus*. The droplets are rich in oxalic acid

Flow of current assimilate drives soil respiration

by a green dye tagged to an antibody against glomalin.

myco-heterotrophic plants



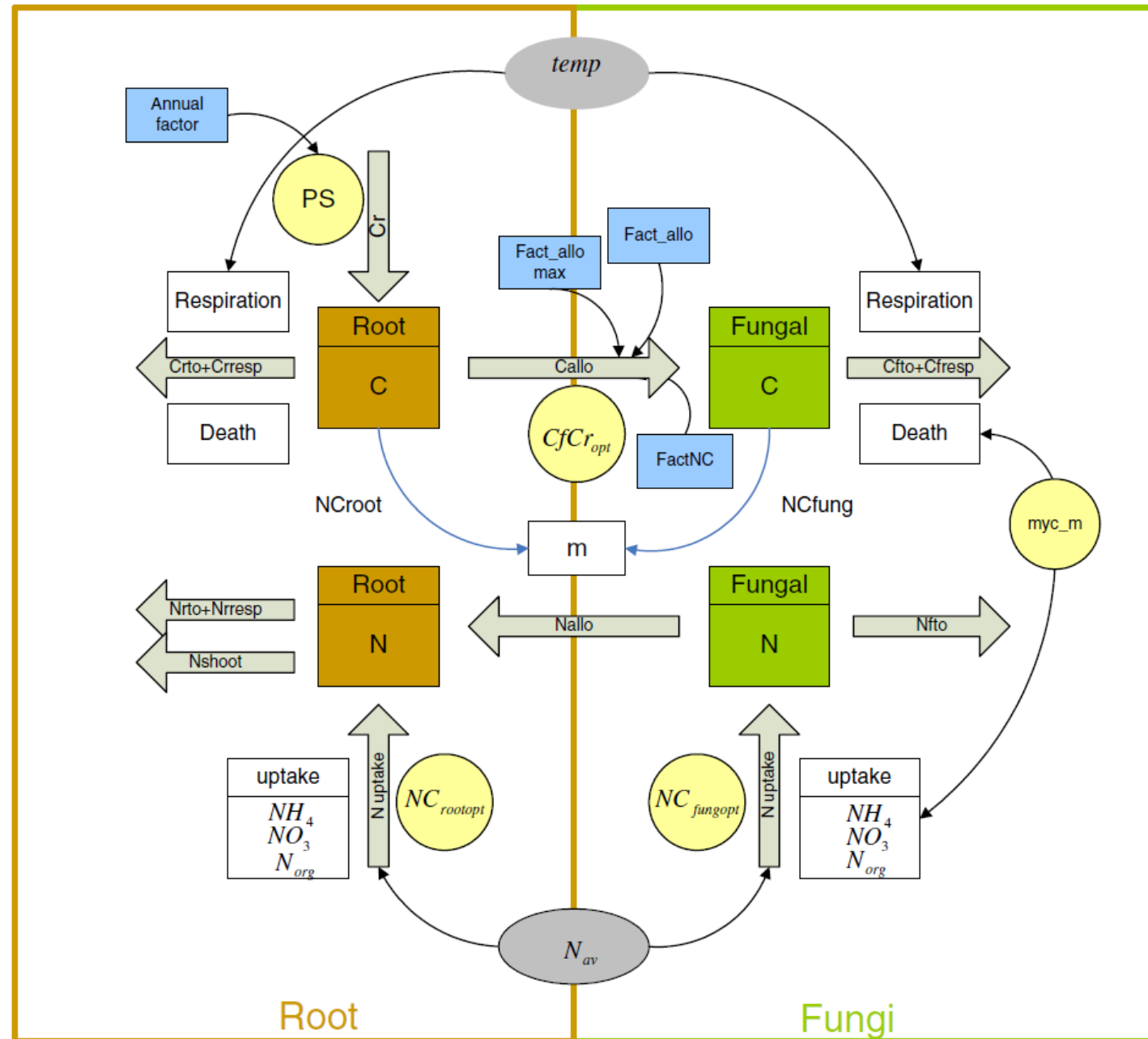
© Jim Stueck @ USDA-NRCS PLANTS Database

3. Results

Finlay 2008

# MYCOFON model

3. Results



Meyer et al. 2010 (PS)



# MYCOFON model

3. Results

		Total N uptake*	Plant N supply*
1995	(normal)	231	158
1996	(dry)	237	155
1997	(wet)	271	182

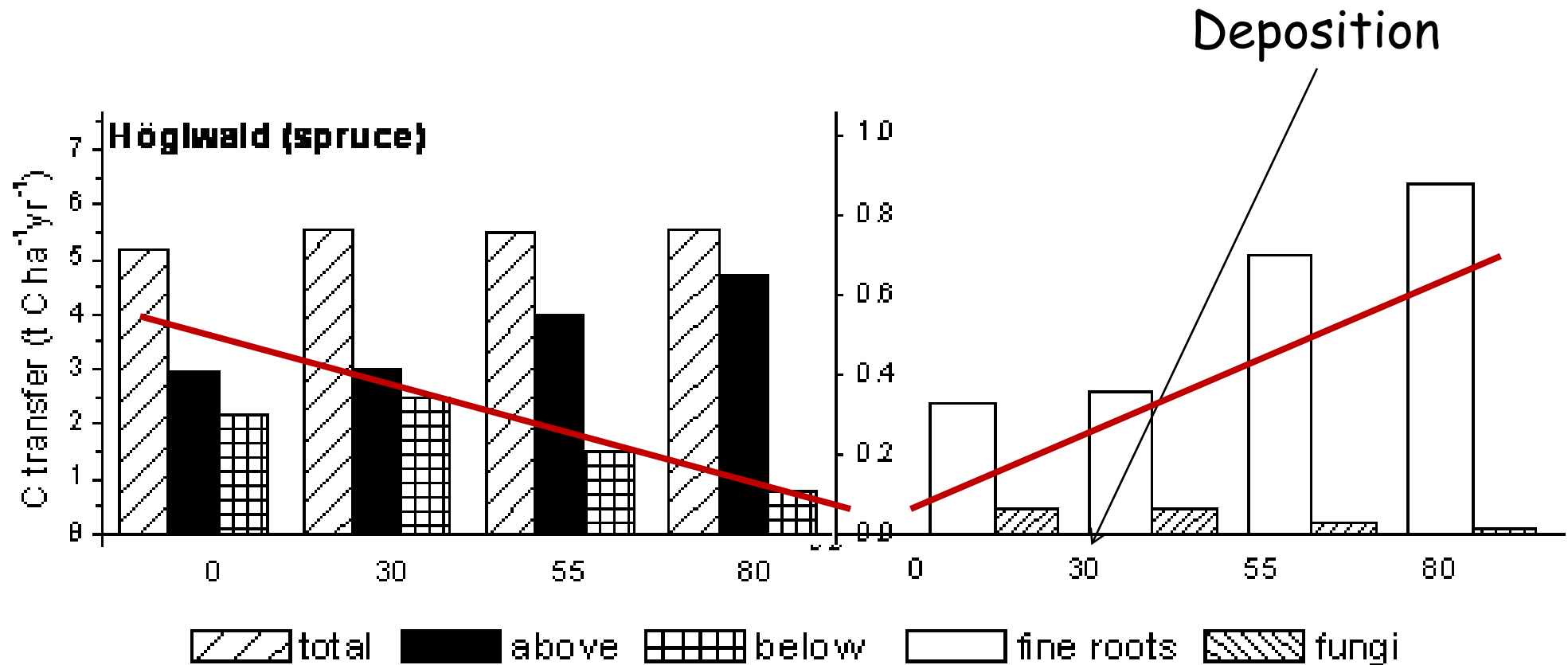
\*kg ha<sup>-1</sup> a<sup>-1</sup>

→ N turnover increased app. 1.5 fold  
(results are preliminary)

Meyer et al. subm (EJFR)

# MYCOFON model

## 3. Results



→ Belowground allocation decreases with N supply (results are preliminary)

Meyer et al. subm (EJFR)

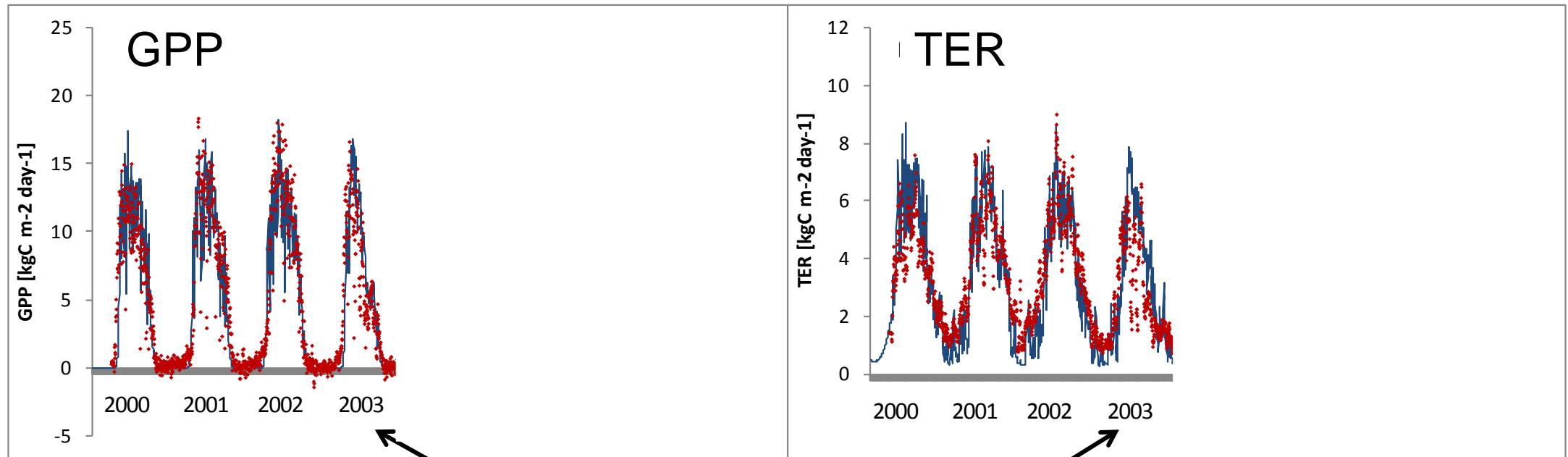
# Example: Physiological adjustments: Hesse/Beech





# Example: Physiological adjustments: Hesse/Beech

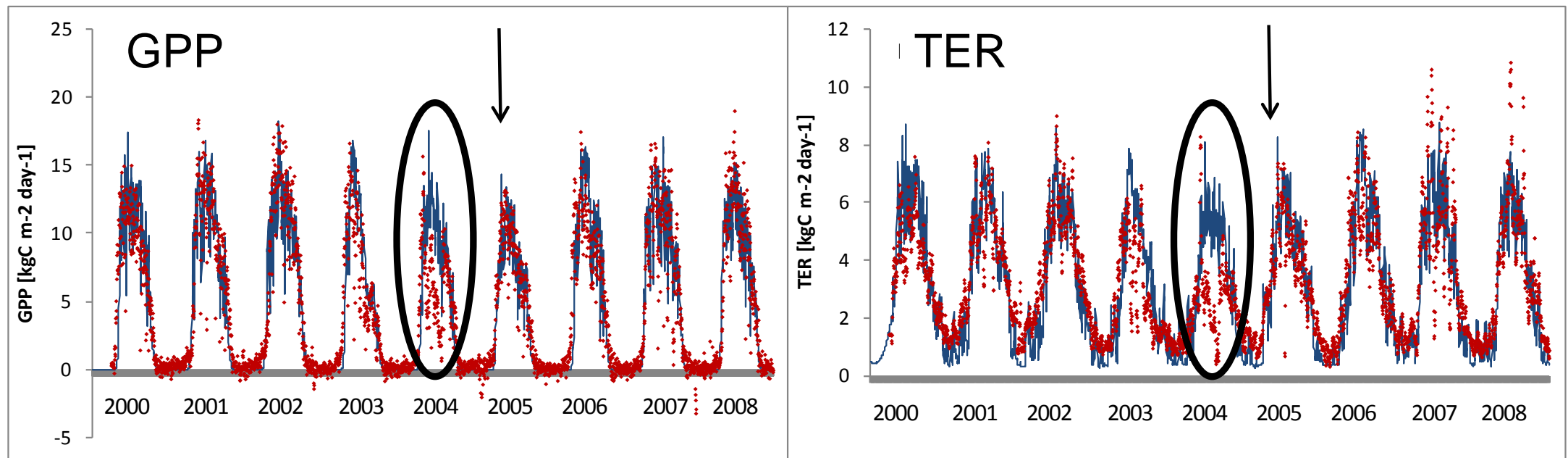
- Parameter adjusted to meet average annual NEE exchange
- Model constrained with forest inventory data
- Model evaluated with soil water and transpiration (1997-2002)



exceptional drought

Grote et al. 2011 (AGRFORMET)

# Example: Physiological adjustments: Hesse/Beech



- Missing tissue destruction by weather extremes?
- Missing resource depletion related to soil processes?
- Both?

Grote et al. 2011 (AGRFORMET)



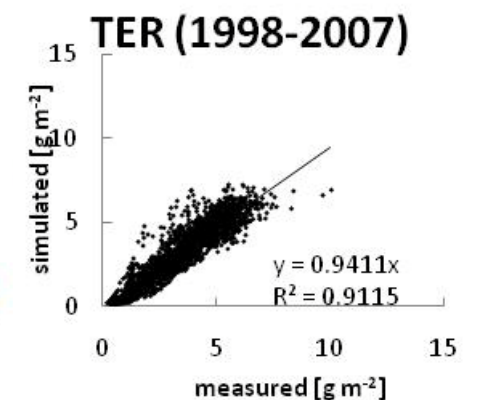
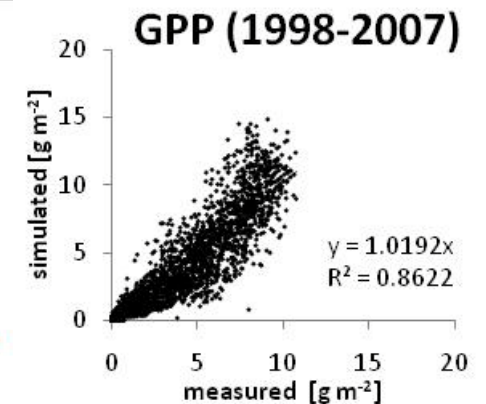
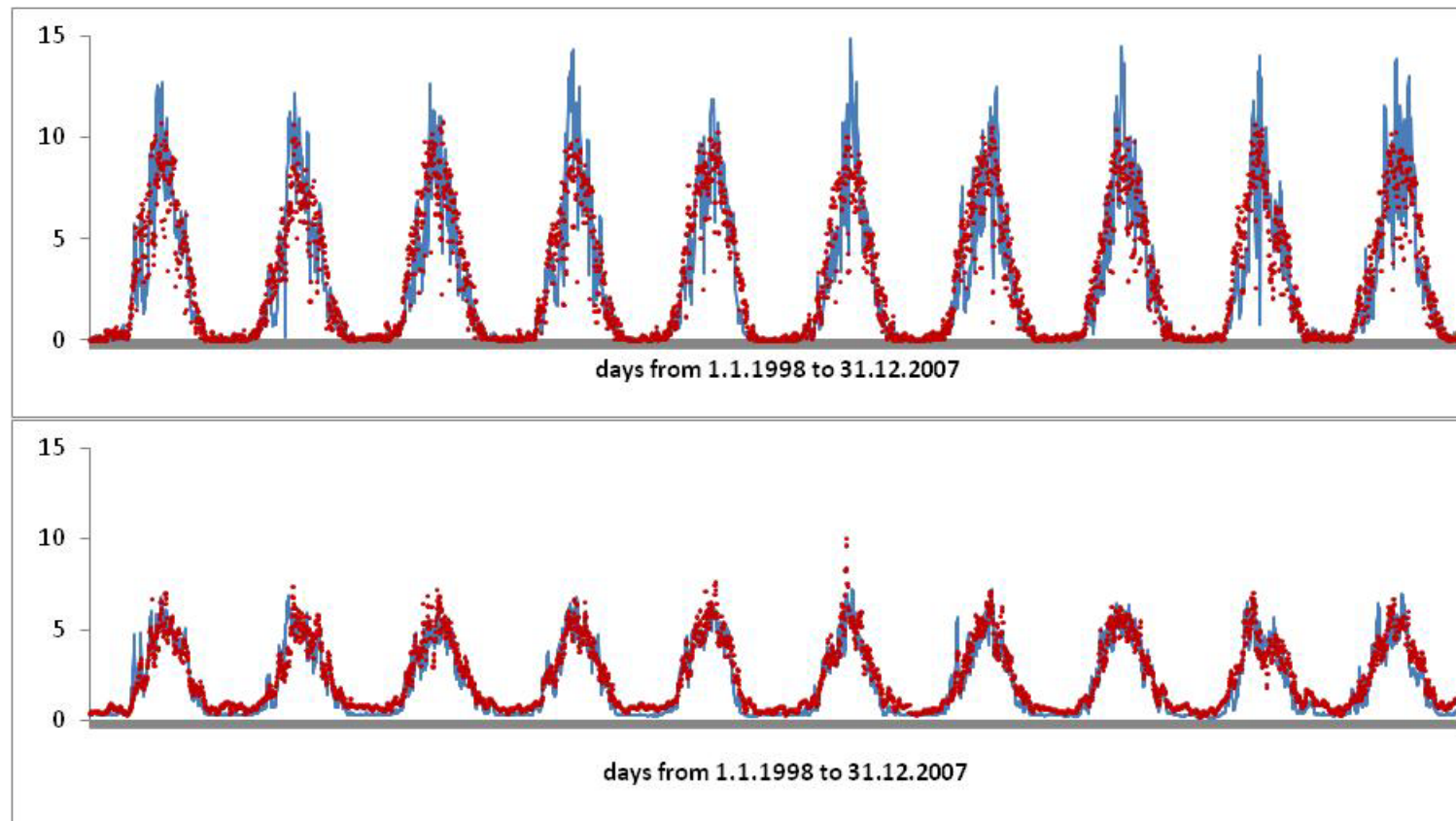
# Example: Physiological adjustments: Hyytiälä/Pine





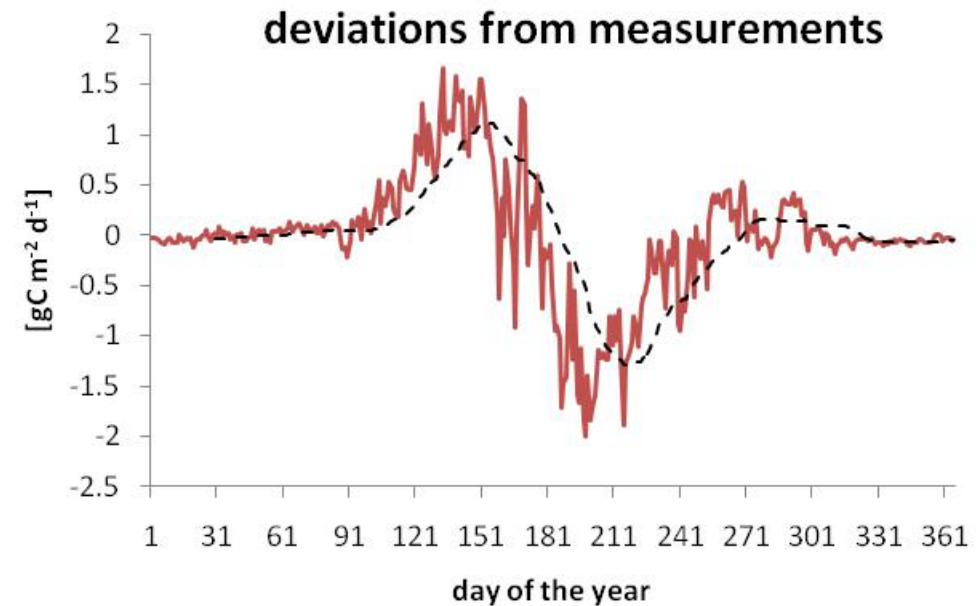
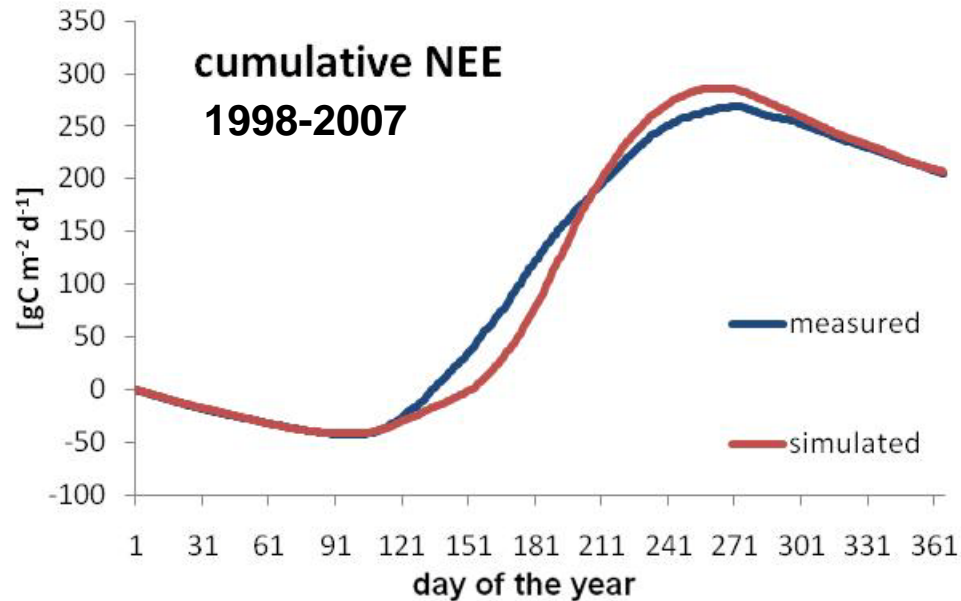
# Example: Physiological adjustments: Hyytiälä

- Parameter adjusted to meet average annual NEE flux  
 Note: Model includes evaluated phenology (litterfall)  
 Note: Model considers empirical seasonality term (Mäkelä et al. 2004)



Grote et al. subm. (FORSYS)

# Example: Physiological adjustments: Hyytiälä



- Seasonality of enzyme activity site specific?
- Missing influence of other plants?
- Both?

Grote et al. subm. (FORSYS)



# Example: Interaction between species: Hyytiälä



Several Species at different places

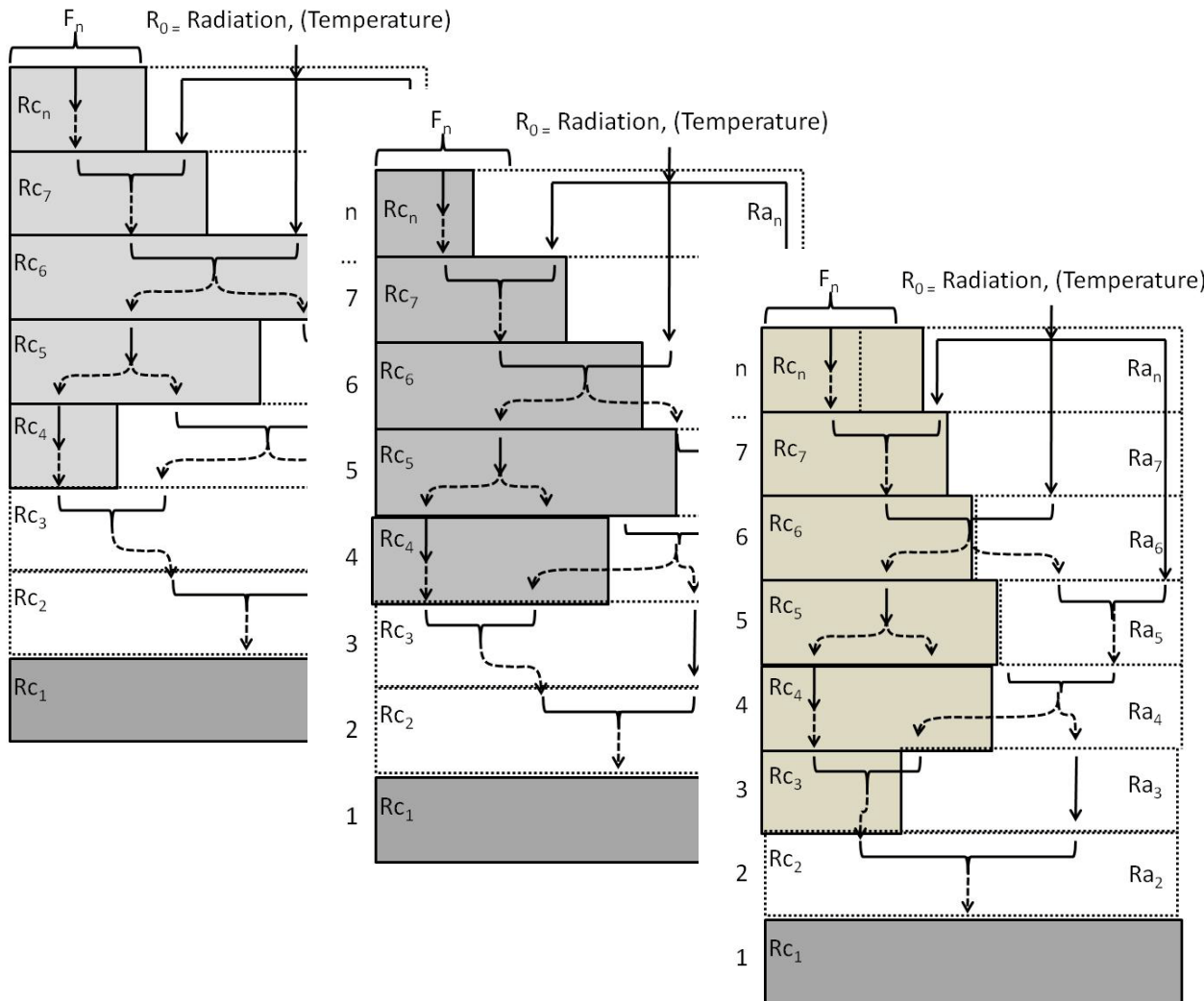
Overstory/Understory

Forest inventory includes significant amounts of spruces and birches!



# Example: Interaction between species: Hyytiälä

## 3. Results



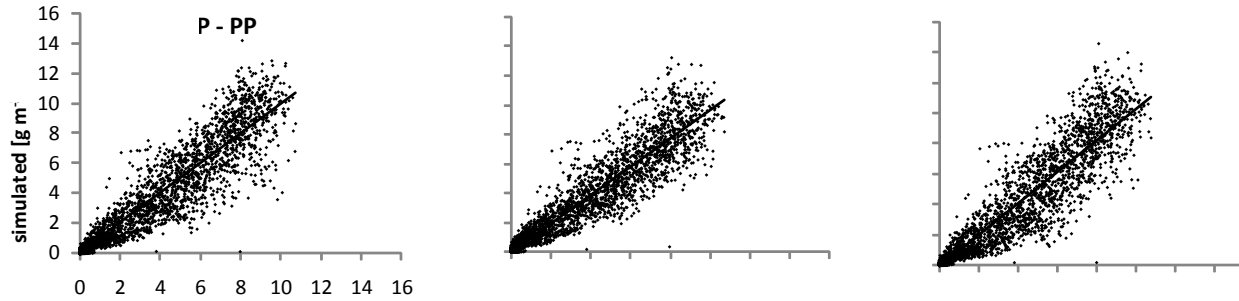
Several Species of the same size  
(WEIGHTED)

Overstory/Understory  
(MIXED)

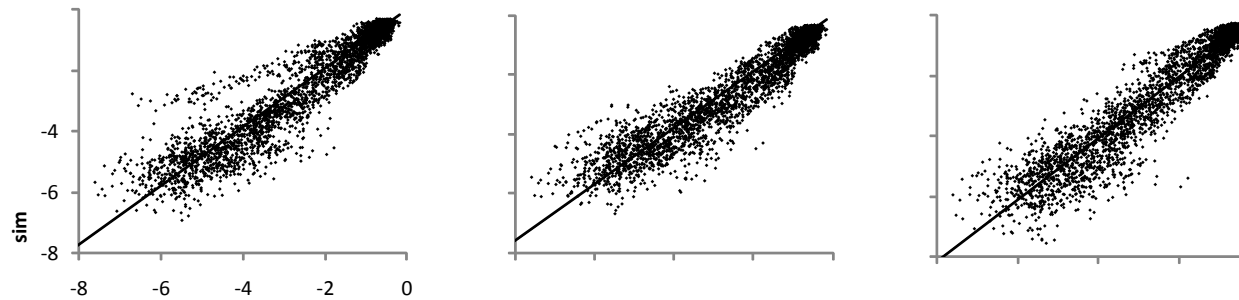
# Example: Interaction between species: Hyytiälä

PURE PINE    WEIGHTED    MIXED

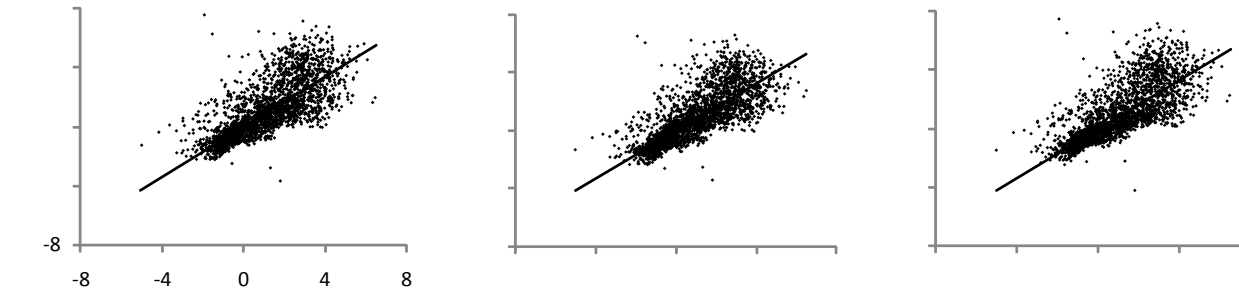
GPP



TER



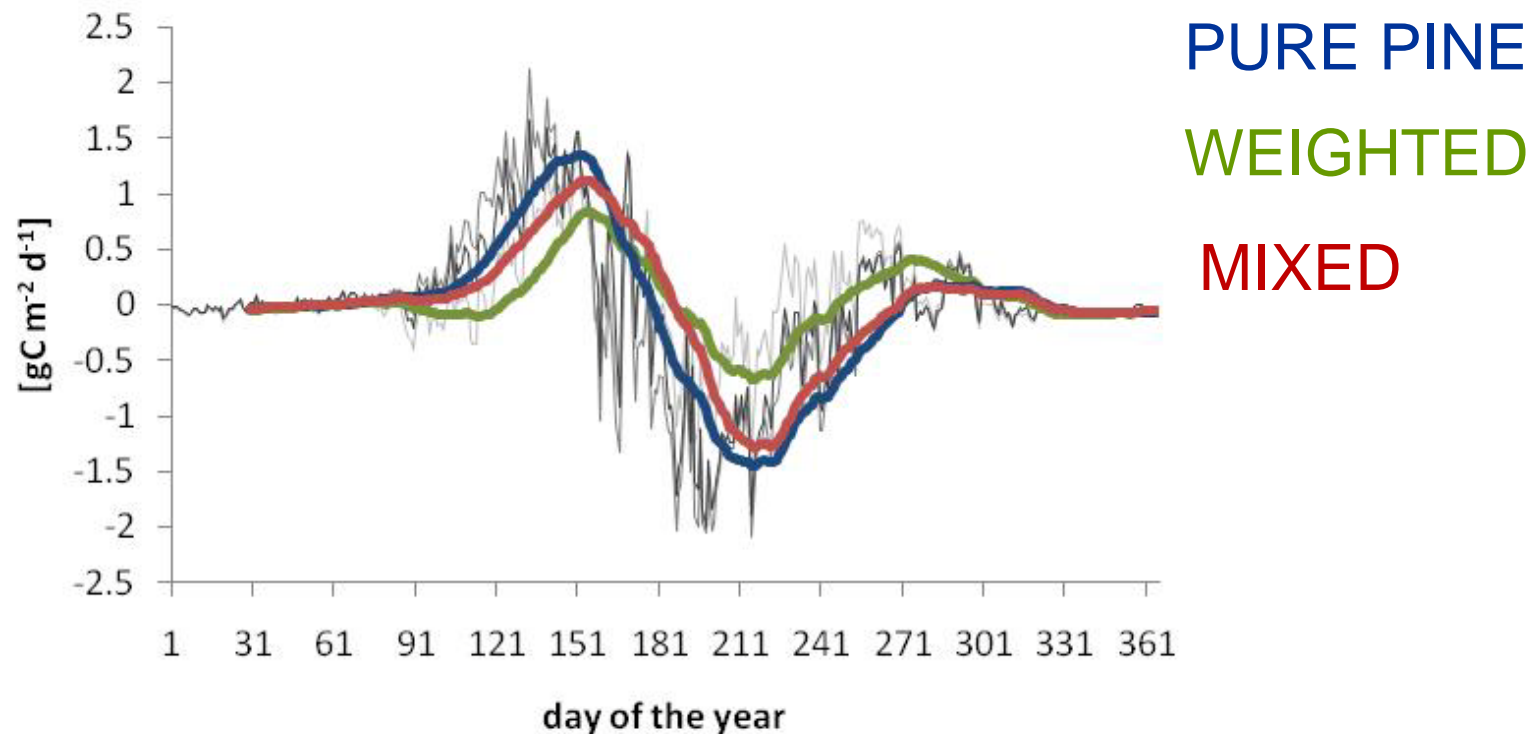
NEE



→ Best statistical results for WEIGHTED and MIXED simulations

Grote et al. subm. (FORSYS)

# Example: Interaction between species: Hyytiälä



Best dynamical results for WEIGHTED simulations

- Stand structure matters!
- ... and open questions still remain

Grote et al. subm. (FORSYS)



## Major deficits considering long-term/one-generation modeling:

- **Soil processes (mycorrhiza, phosphorus)**  
(LeRoux et al. 2001, Landsberg 2003, Hobbie 2006, Fontes et al. 2010, McGuire & Treseder 2010)
- **Acclimation, incl. Downregulation and long-term Damages**  
(Constable & Friend 2000, LeRoux et al. 2001, Landsberg 2003, Litton et al. 2007, Hanson et al. 2004, Atkin et al. 2007, Leuzinger et al. 2011)
- **Disturbances (i.e. fire, insects, management)**  
(Thornton et al. 2002, Running 2008, Fontes et al. 2010, Seidl et al. 2011)
- **(Short-term) Interaction between species/species groups**  
(Moorcroft et al. 2003)

Physiologically-based models are not (yet) suitable for applications on long-term environmental changes

Major progress can be expected with new model approaches that consider an ecosystem as multi-organismic and describe species interaction.

