Metsä Tieto Osaaminen METLA Hyvinvointi

Leaf area (and soil) controls on boreal forest water, energy and carbon fluxes

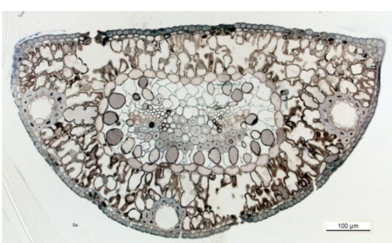
Samuli Launiainen

Gaby Katul, Pasi Kolari, Ari Laurén

TERENO International Conference, 1.10.2014 Bonn, Germany

APES (Atmosphere-Plant Exchange Simulator)

- Vertically resolved 1-D SVAT-model for (boreal) forests
- Elementary scale: a horizontally homogenous canopy layer
- Upscaling from leaf/shoot/forest floor processes to stand scale exchange

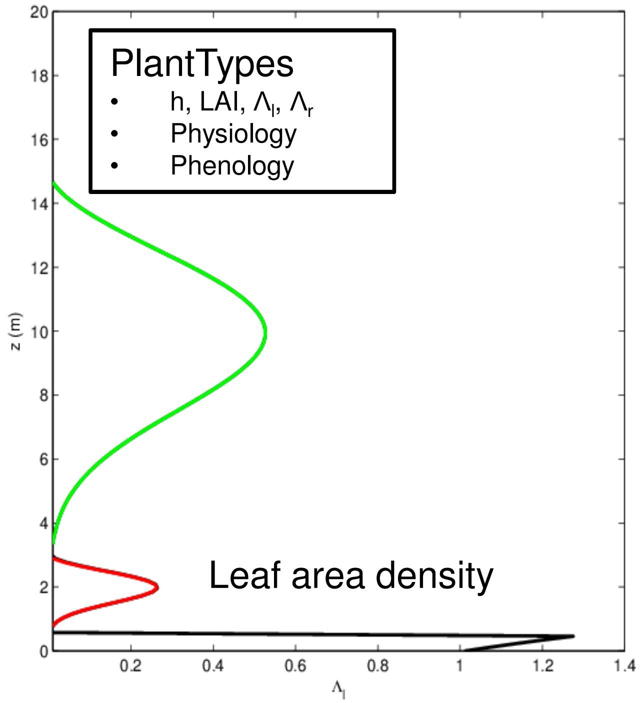


Launiainen et al., 2014 (Ecol. Mod., manuscript)

Upper boundary conditions (meteorology, ½ or 1 h time scale)

Site parameterization

PlantTypes
- h, LAI, Λ_l, Λ_r
- Physiology
- Phenology



BottomLayer (bryophytes)

SoilProfile
- WRC, hydraulic conductivity, thermal properties
- Soil respiration

Lower boundary conditions (at bottom of SoilProfile)

Vascular plant processes

- Sunlit / shaded foliage at each layer for each species
- Farquhar –model (Farquhar et al., 1980)
- Variant of optimal stomatal closure theory (Medlyn et al., 2012)
- Leaf energy balance
- Feedback to soil water via macroscopic root uptake scheme (Volpe et al.,2013)
- Ψ_{root} (or Ψ_{leaf}) adjust stomatal slope g_1 and V_{cmax} & J_{max}

Bottom layer processes (mosses)

- Water & energy balance
- moss-air gas & energy exchange (Rice et al, 2001; Williams & Flanagan, 1996;1998)

SoilProfile

- 1-D Richards equation & Fourier equation
- Flexible boundary conditions incl. lateral flows
- Bulk soil respiration rate (auto+heterotrophic)

Microclimate

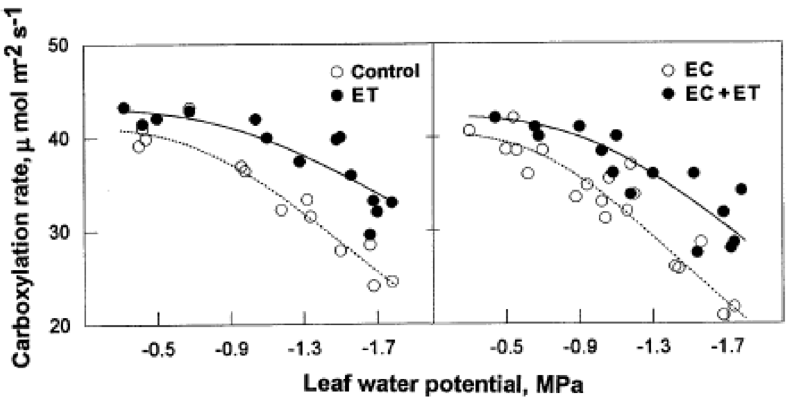
- Short-wave & long-wave radiation (Zhao & Qualls, 2005) with adaptations for clumped conifer canopies
- Multi-layer rainfall interception (Watanabe & Mizutani, 1996; Tanaka, 2002)
- 1st-order turbulence closure (momentum & scalar exchange)

Soil-leaf feedbacks

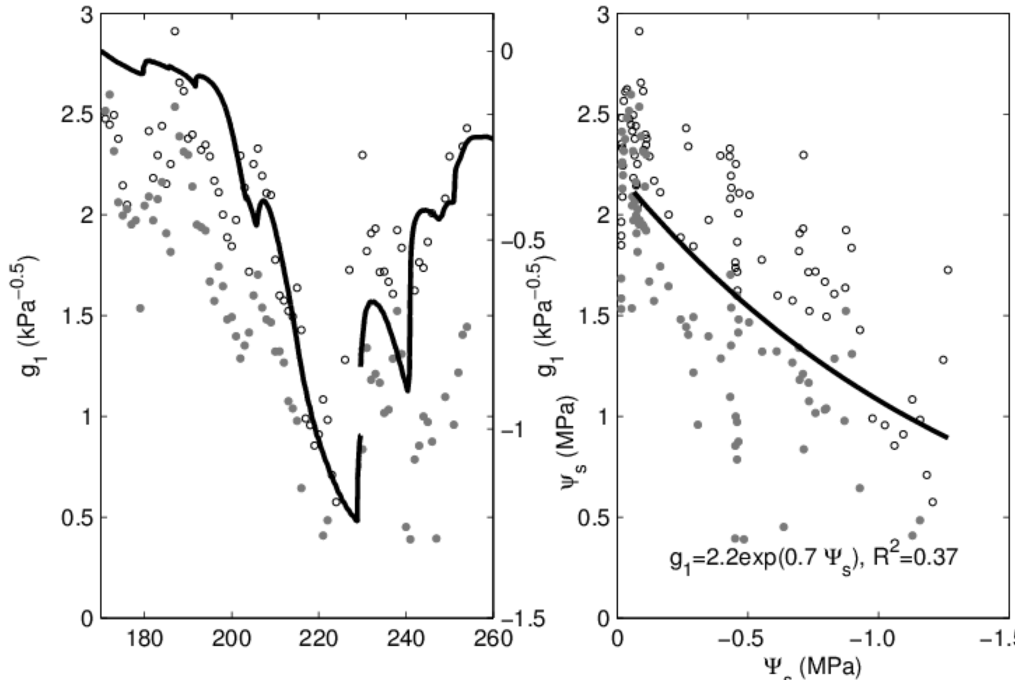
Biochemical:
Vcmax(Ψ), Jmax(Ψ)

Stomatal: $g_1(\Psi)$, $g_1(\theta)$, …

$$g_s^* \approx g_0 + \left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a}.$$



Kellomäki & Wang (1996) Tree Phys.



Launiainen et al. 2014 (manuscript)

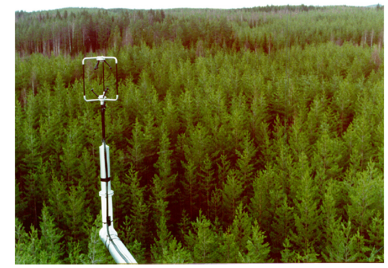
Test case: Hyytiälä Scots pine stand

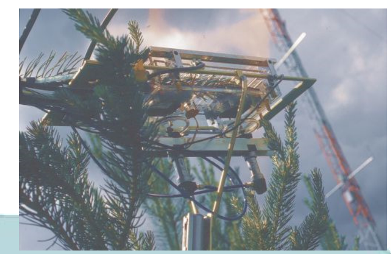
Parameterization for SMEAR II –site:

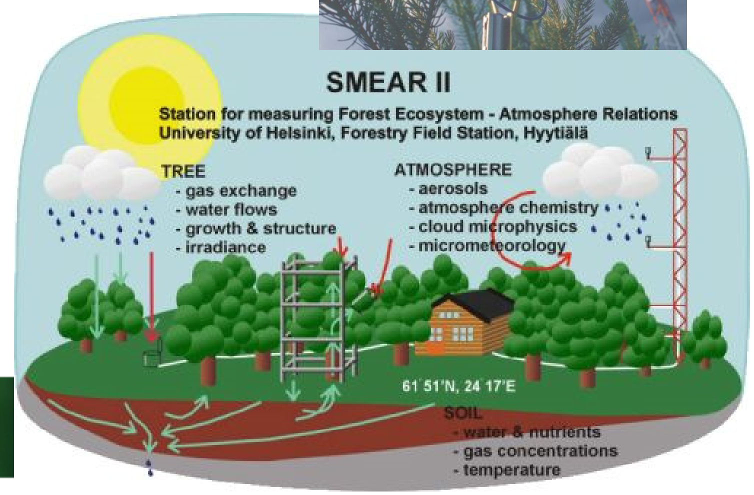
- Biomass & LAI measurements
- Soil water retention curves, hydraulic conductivity measured
- Species parameterization for: i) pine, ii) undergrowth, iii) field layer, iv) feather mosses
  - Literature, leaf & shoot gas exchange data
- Forcing: ½ h meteorology

Independent validation:

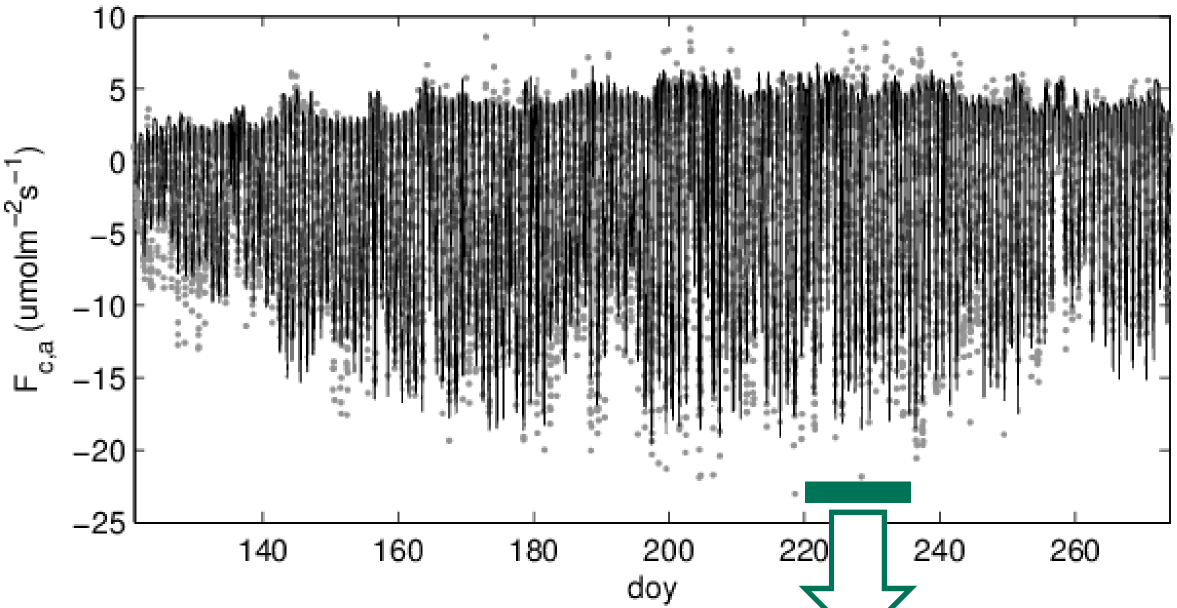
- EC-fluxes above and in sub-canopy
- Radiation measurements, scalar gradients
- Ground heat flux, soil T & water content profiles

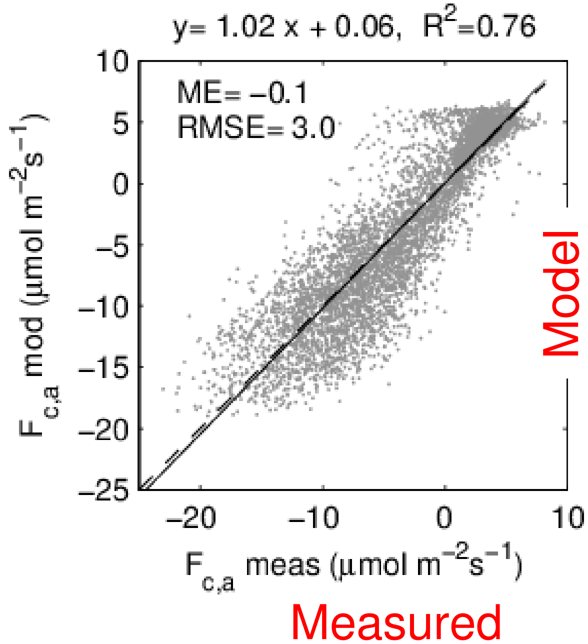


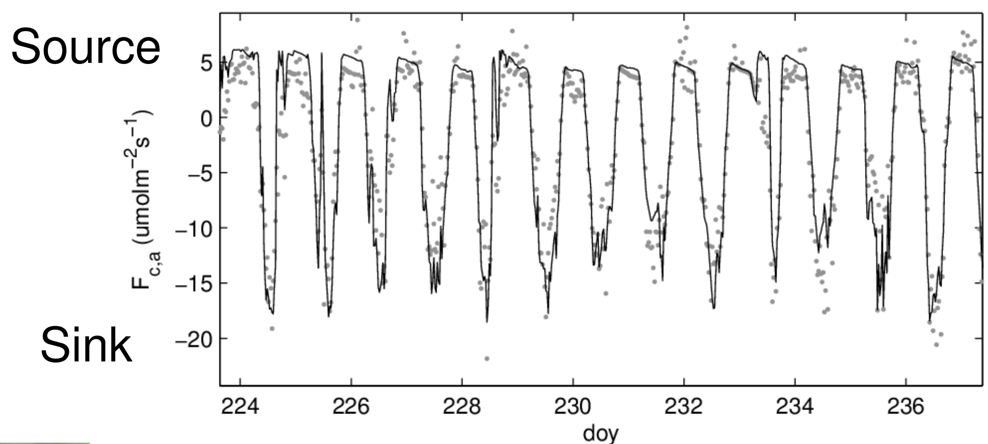




Stand NEE in ½h timescale

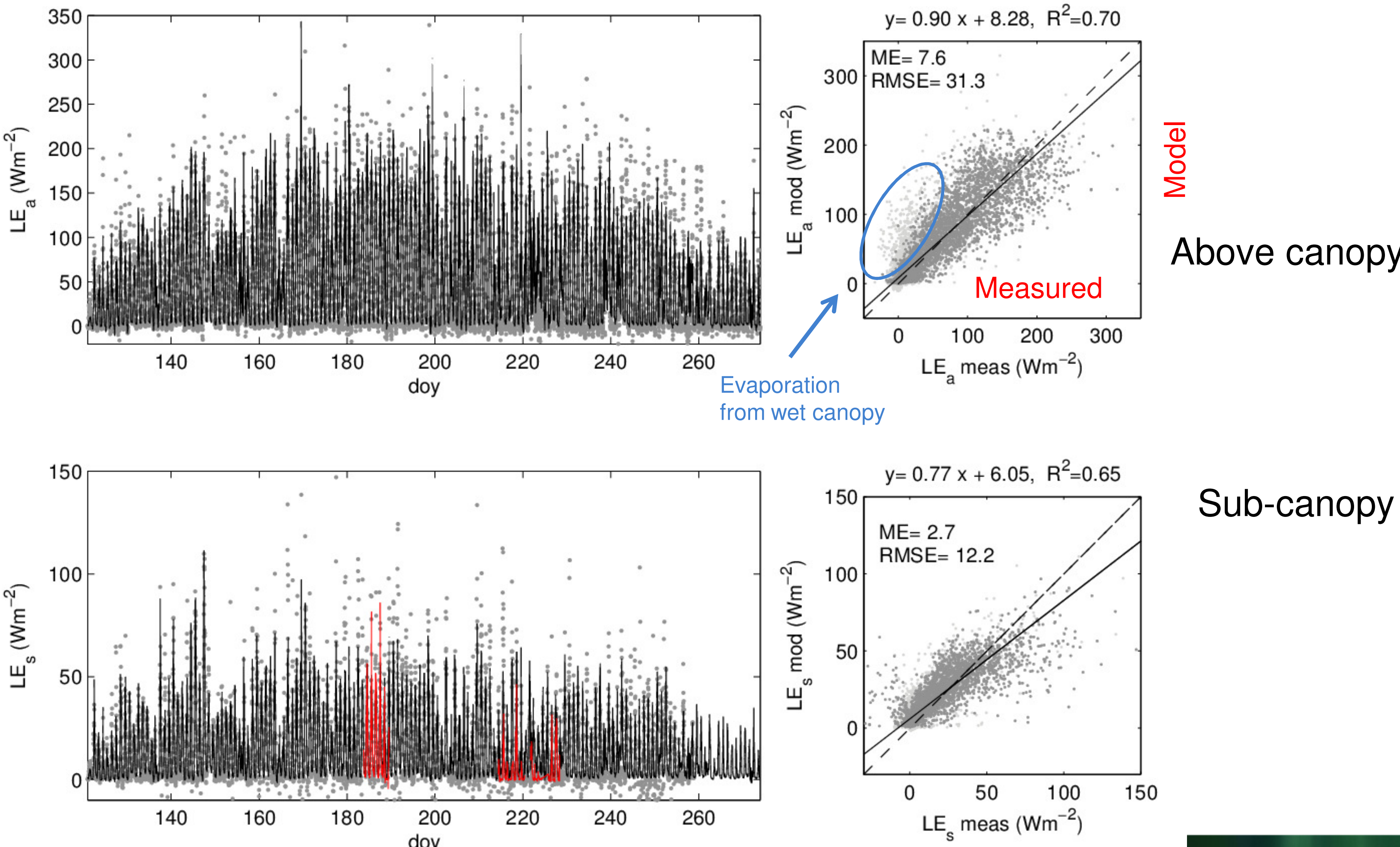




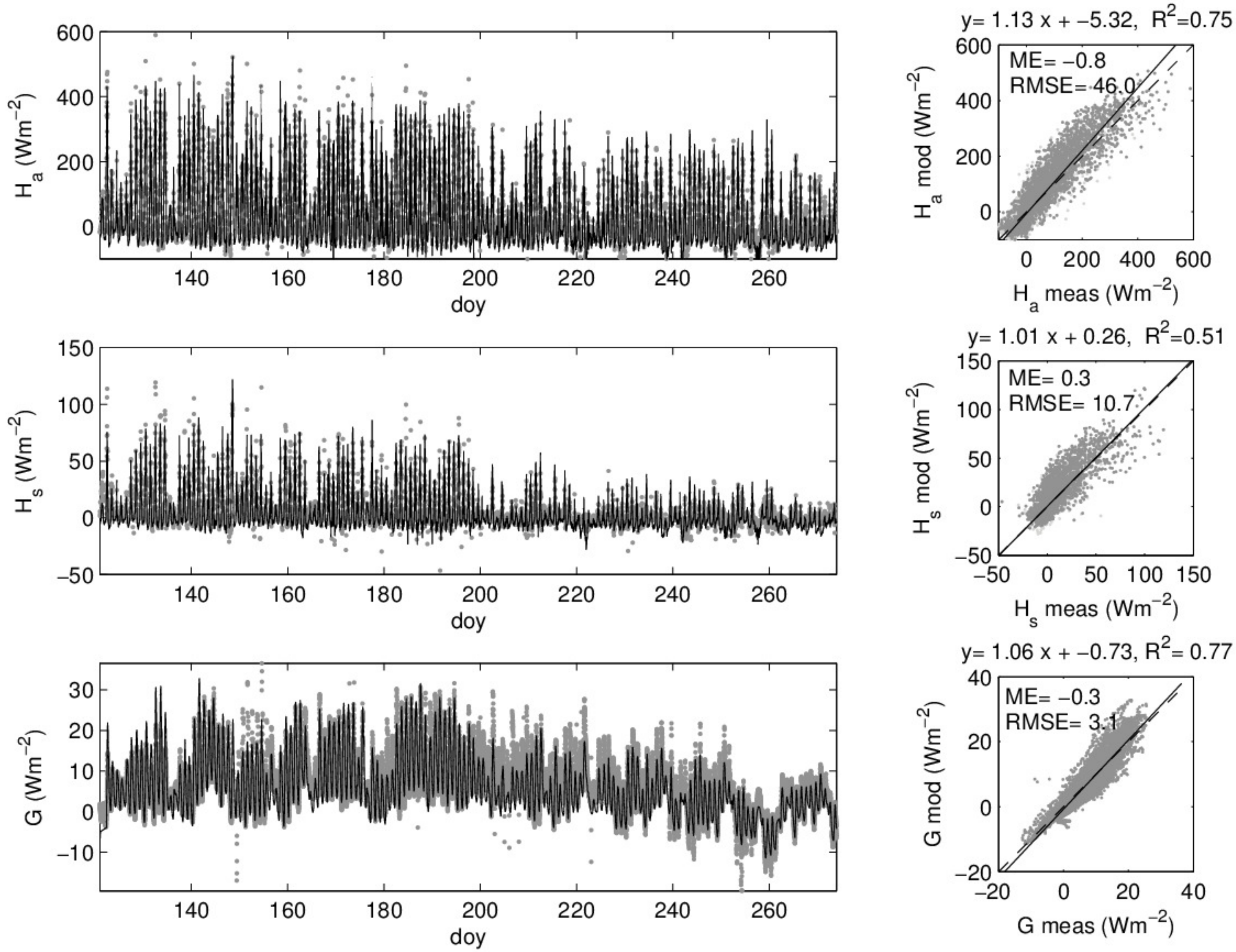


2005 May-Sept

Latent heat flux (i.e. ET)



Heat fluxes



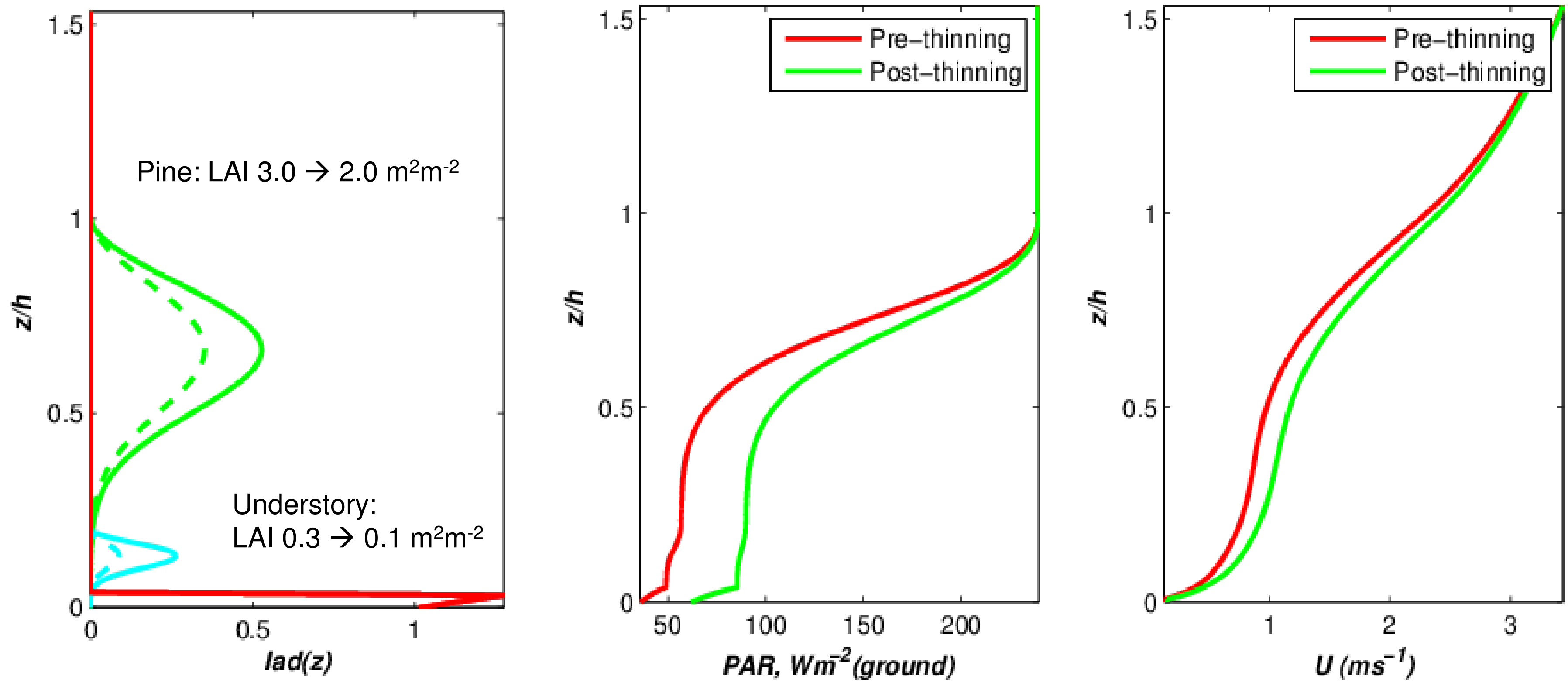
Above canopy

Sub-canopy

Ground heat flux at 10 cm depth

Thinning

Most strongly altered microclimatic variables

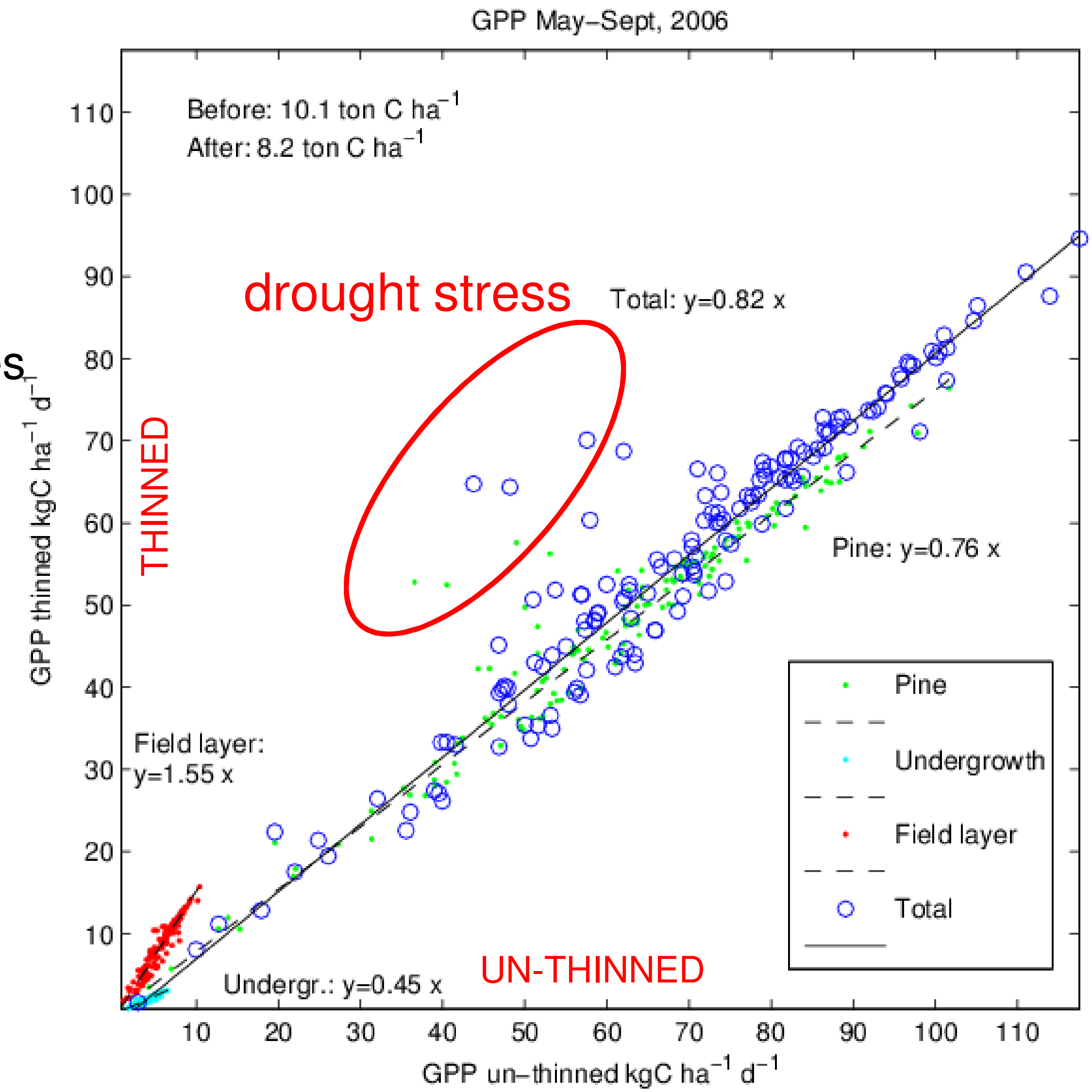


Field layer:
LAI 0.7 m^2m^{-2}

Thinning impact on GPP

- Removal of 33% of pine LAI → -24% GPP
- …but +15% if scaled per unit remaining pine LAI
- … + ~25% if scaled per nr. trees remaining
- Observations: increase in annual volume growth >= 20% during first 5 yr after thinning

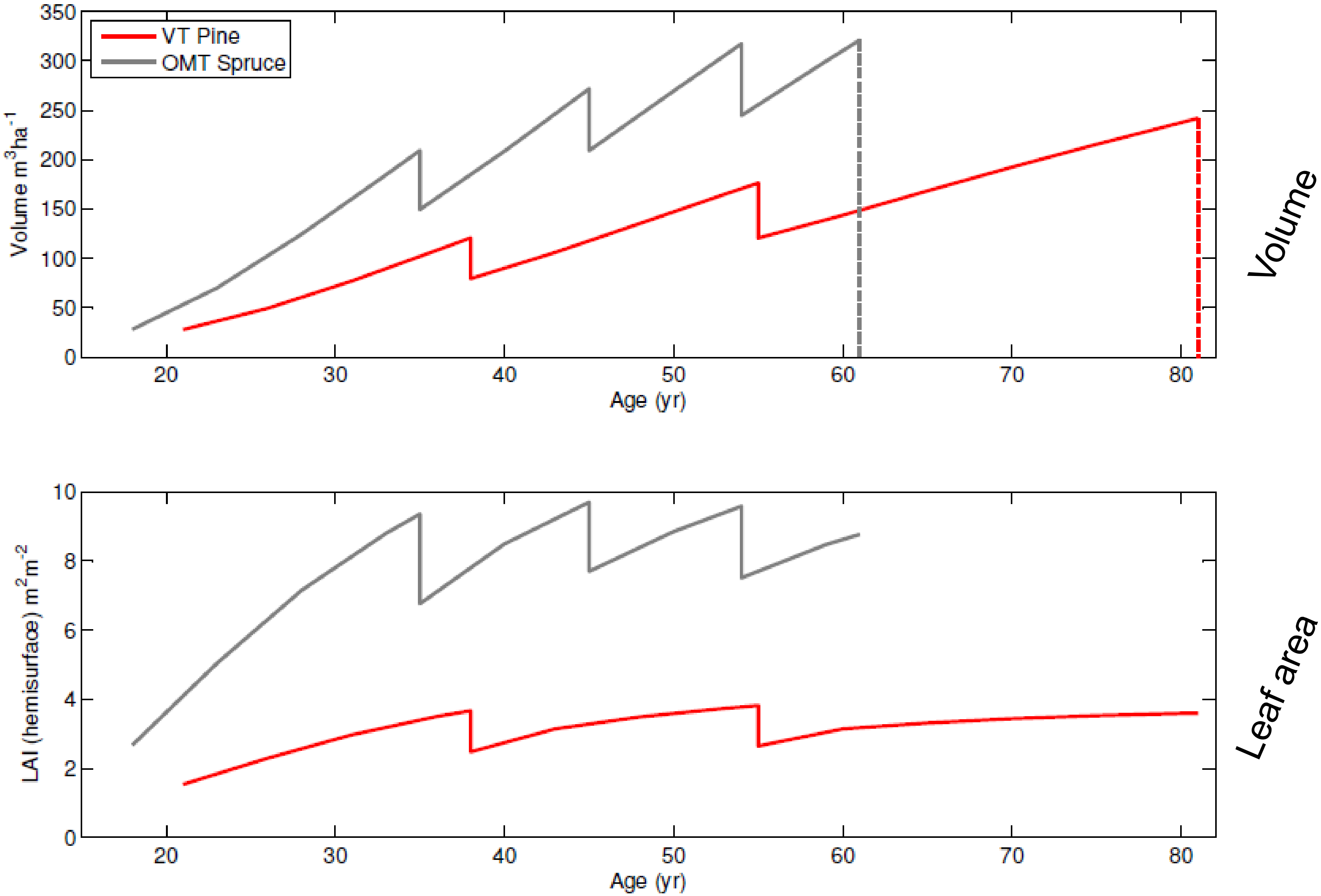
- **Light competition**
- **Water resources**
- Fertilization effect not considered



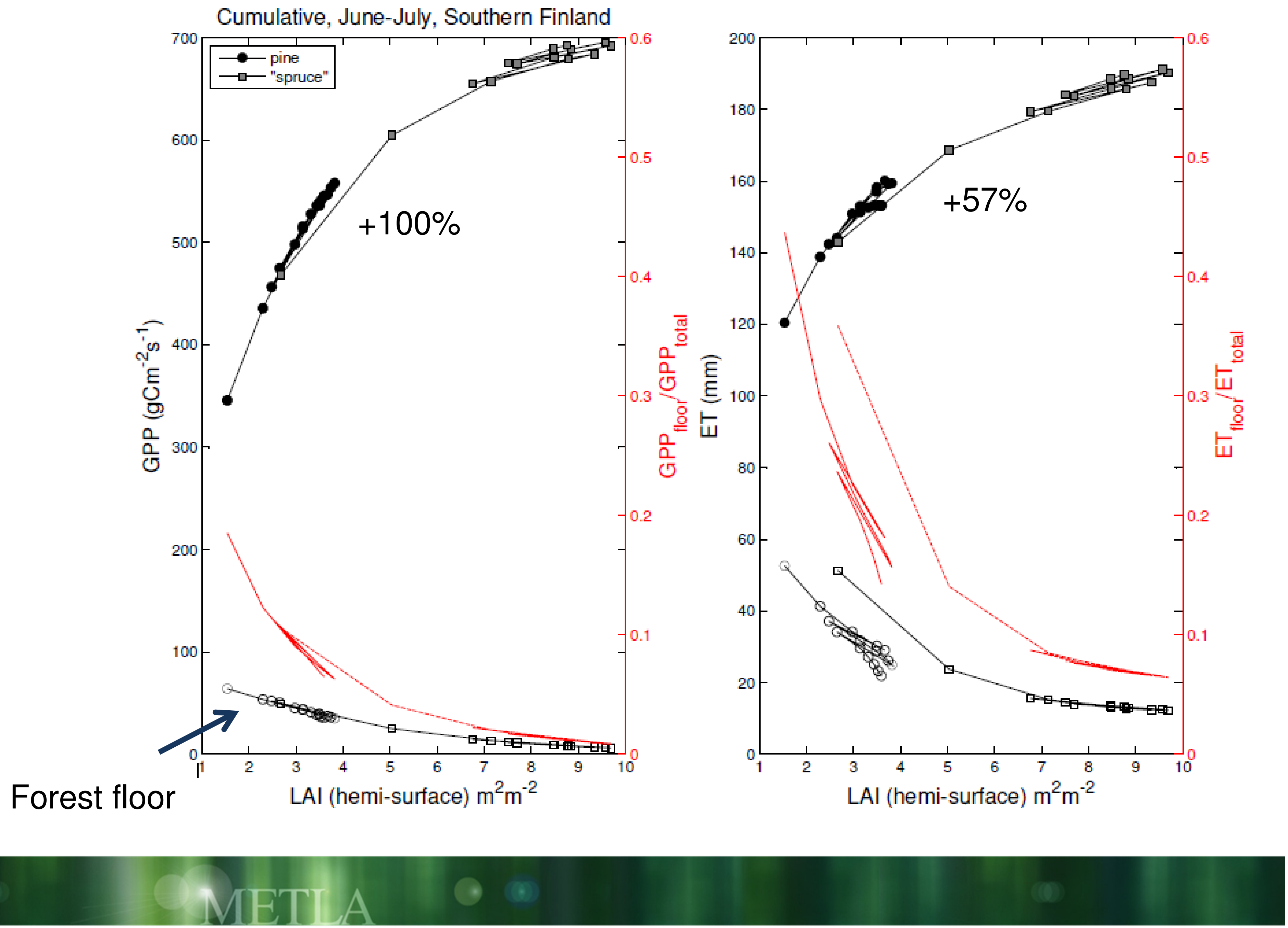
Rotation: Growth & management

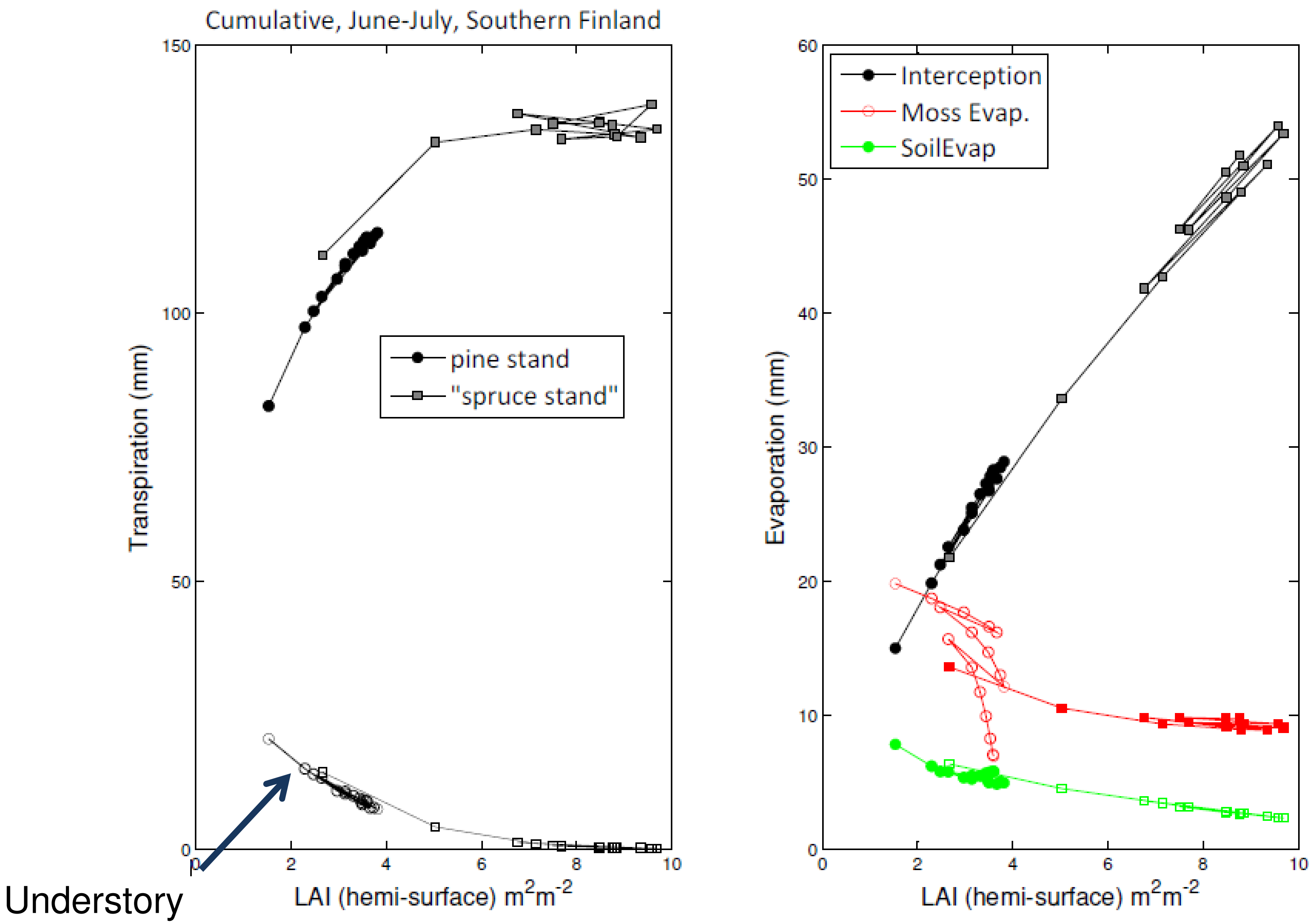


- Stand growth & management: statistical growth model MOTTI (Hynynen et al., 2006),
- Understory & bottom layer vegetation: biomass equations (Muukkonen & Mäkipää, 2006 Bor. Env. Res)
- Southern Finland, a moist year (i.e. minimal soil controls), 2 month cumulative values (June-July)



MOTTI statistical forest growth model (Hynynen et al., 2006)


Cumulative, June-July, Southern Finland
pine
"spruce"
+100%
+57%
GPP (gCm-2s-1)
GPPfloor/GPPtotal
ET (mm)
ETfloor/ETtotal
LAI (hemi-surface) m2m-2
LAI (hemi-surface) m2m-2
Forest floor
METLA


Cumulative, June-July, Southern Finland
Transpiration (mm)
LAI (hemi-surface) m^{2}m^{-2}
pine stand
"spruce stand"
Understory
Evaporation (mm)
LAI (hemi-surface) m^{2}m^{-2}
Interception
Moss Evap.
SoilEvap

Conclusions

- Biophysical & physiological theory: most parameters can be measured directly
  - Validation for a dense spruce stand needed!
- Does forest structure matter?
  - GPP rather sensitive to LAI
  - ET more conservative; compensating processes
  - Interception the main factor between ET- LAI - relationship in dense stands
- Do species matter – role of functional biodiversity?
  - Photosynthetic parameters well known, species-specific WUE and drought response data are lacking

Thank you for your attention!

samuli.launiainen@metla.fi


metsä
METLA
TIETO
osaaminen
hyvinvointi
Kiitos