Transregional Collaborative Research Center 32

Characterizing heat and mass flux patterns in agricultural crops using landsurface and crop modelling approaches

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TR32 – B5 in cooperation with B4, B6, C3, D2, Z1, Z2, Z3, Z4

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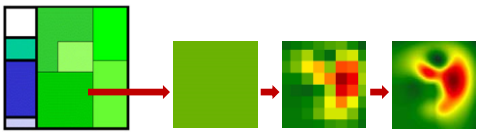
Spatial patterns in an agricultural landscape – Selhausen, Germany

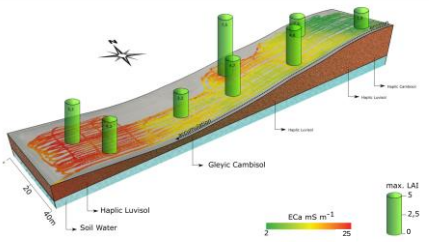
Google Maps 2018

Level of detail in spatial patterns in agricultural landscapes

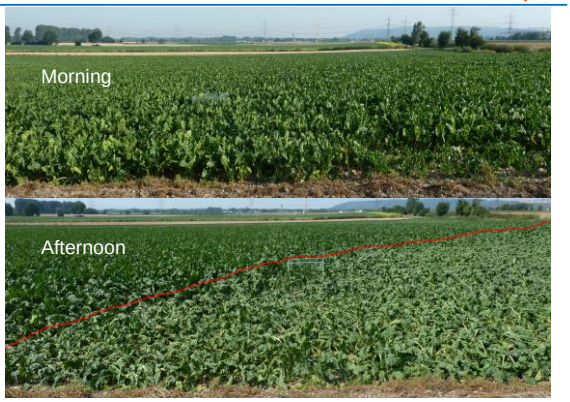


Increasing level of spatial detail

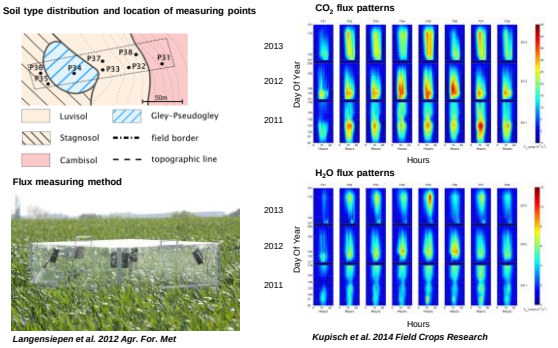
Changes in soil electric conductivity indicate heterogeneity in soil physical properties which affect leaf area growth - Selhausen, 2011



Sugar beet response to an abrupt change in spatial soil conditions



Patterns of CO_2 and H_2O fluxes in a heterogeneous wheat field Selhausen 2011, 2012 and 2013



Langensiepen et al. 2012 Agr. For. Met

Kupisch et al. 2014 Field Crops Research

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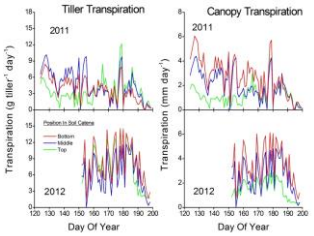
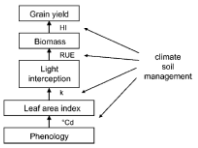
Transpiration at different positions in a soil catena

Langensiepen et al 2014



Langensiepen et al 2013

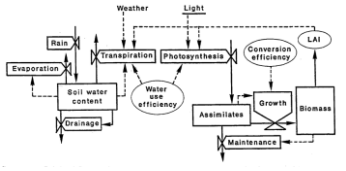
Typical structure of crop models



Carberry 2003

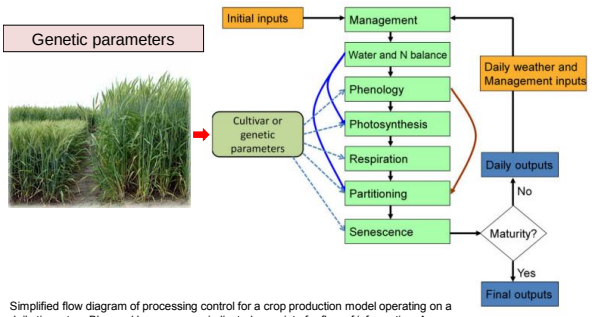
Example

SUCROS – Simple and Universal CROp growth Simulator)



van Laar, Goudriaan and van Keulen 1997

Crop models: Extended framework



Simplified flow diagram of processing control for a crop production model operating on a daily time step. Blue and brown arrows indicate key points for flow of information. Arrows with dashed lines indicate inputs for cultivar-specific or genetic parameters. Possible feedbacks (e.g. of partitioning on water use and photosynthesis) are not shown.

Boote et al 2013

Improved crop model parameterization in CLM 3.5

Photosynthesis parameters

Crop type	$vcmx25$ [a]	mp [b]	$\varphi 25$ [c]	$slatop$ [d]	$dslatdt$ [e]	$leafcn$ [f]	$flnr$ [g]
ctrl crop	na	9.0	0.06	0.050	0.0	25.0	0.10
sugar beet	118.0	6.7	0.062	0.020	0.0	10.0	0.15
winter wheat	80.0	7.0	0.0476	0.028	0.0	14.0	0.3

[a] max rate of carboxylation at 25°C [μmol CO_2/m^2/s]
[b] slope of conductance-to-photosynthesis relationship [/]
[c] quantum efficiency at 25°C [μmol CO_2/μmol photon]
[d] specific leaf area at top of canopy [m^2/gC]
[e] dSLA/dLAI [m^2/gC]
[f] leaf C:N [gC/gN]
[g] fraction of leaf N in the Rubisco enzyme [gN Rubisco/gN leaf]

Soil water potentials at full stomatal opening and closing

Crop type	$smpso$ [h]	$smpsc$ [i]
ctrl crop	-7.74×10^3	-2.75×10^5
sugar beet	-4.20×10^3	-1.65×10^5
winter wheat	-7.04×10^3	-1.60×10^5

[h] soil water potential at full stomatal opening [mm]
[i] soil water potential at full stomatal closure [mm]

Optical parameters

Crop type	$rhol_{vis,NIR}$ [j]	$rhos_{vis,NIR}$ [k]	$taul_{vis,NIR}$ [l]	$taus_{vis,NIR}$ [m]
ctrl crop	0.11,0.58	0.36,0.58	0.07,0.25	0.22,0.38
sugar beet	0.10,0.46	0.30,0.46	0.09,0.25	0.22,0.78
winter wheat	0.10,0.42	0.30,0.42	0.08,0.25	0.25,0.95

[j] leaf reflectance (visible, near-infrared) [/]
[k] stem reflectance (visible, near-infrared) [/]
[l] leaf transmittance (visible, near-infrared) [/]
[m] stem transmittance (visible, near-infrared) [/]

Aerodynamic parameters

Crop type	$z0mr$ [p]	$displar$ [q]	$dleaf$ [r]
ctrl crop	0.12	0.68	0.04
sugar beet	0.12	0.68	0.28
winter wheat	0.13	0.70	0.05

[p] ratio of the momentum roughness length to canopy top height [/]
[q] ratio of displacement height to canopy top height [/]
[r] characteristic leaf dimension [m]

Sulis et al 2015

Consideration of crop specific types improves the calculation of energy balance components and gross primary production in CLM 3.5

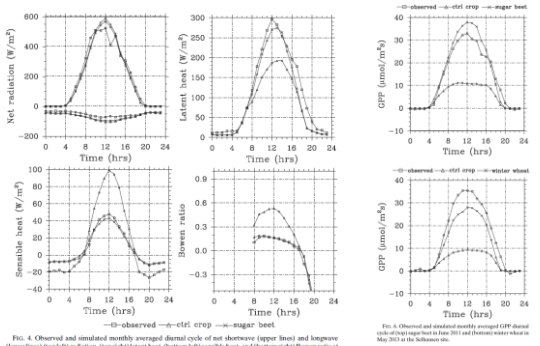


FIG. 4. Observed and simulated monthly averaged diurnal cycle of net shortwave (upper lines) and longwave (lower lines) (top left) radiation, (top right) latent heat, (bottom left) sensible heat, and (bottom right) Bowen ratio at the Selhausen site (June 2011).

FIG. 6. Observed and simulated monthly averaged GPP diurnal cycle of (top) sugar beet in June 2011 and (bottom) winter wheat in May 2013 at the Selhausen site.

Sulis et al 2015

CLM-CN: Diagnostic (a) and prognostic crop model (b)

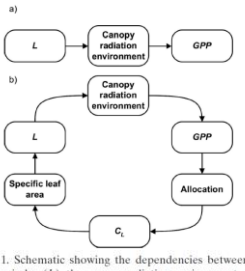
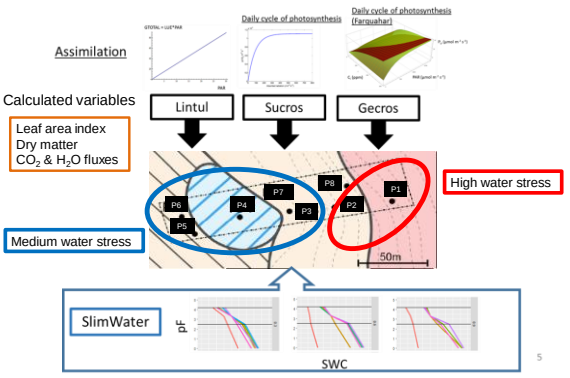


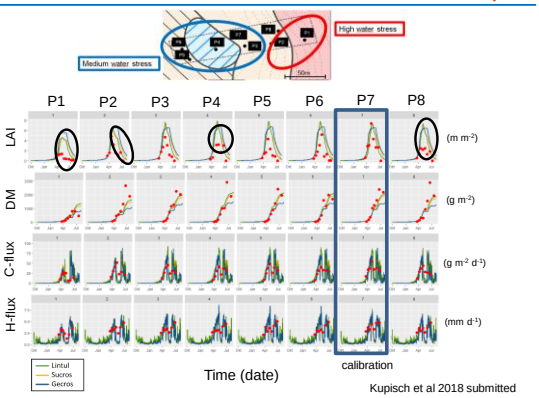
FIG. 1. Schematic showing the dependencies between canopy leaf area index (L), the canopy radiation environment, and GPP for idealized (a) diagnostic and (b) prognostic canopy models, where (b) also illustrates the prognostic model feedback between GPP and L acting through allocation to leaf carbon (C_L) and SLA.

Thornton & Zimmermann 2007

Is increasing crop model detail improving flux calculations? - Calculation setup -

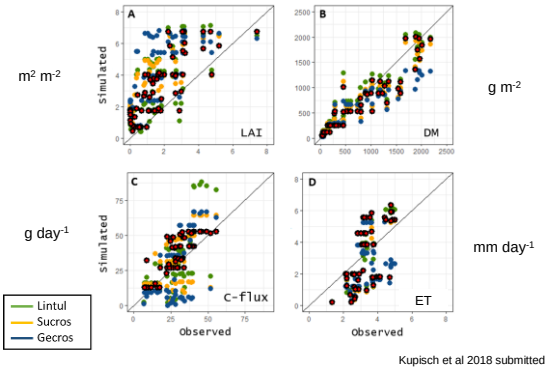


Calculation results of three different crop models: Lintul, Sucros, Gecros Wheat – Selhausen 2011



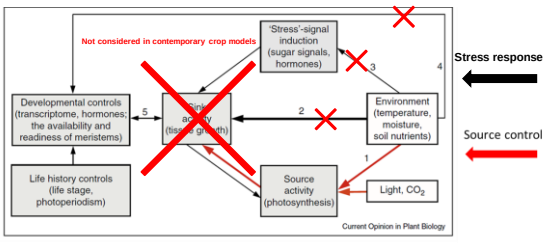
Kupisch et al 2018 submitted

Observed and simulated leaf area index LAI, dry matter DM, canopy carbon flux C and evapotranspiration ET – Wheat, Selhausen 2011



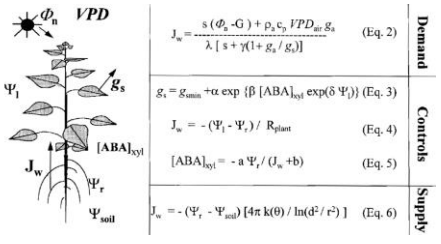
Kupisch et al 2018 submitted

Major pathways of growth control responses to the environment



Körner 2015

B5 + B4 Phase III: How does the hydraulic structure of soil-plant-atmosphere systems respond to **isohydric** and **anisohydric control**?



Tardieu & Simonneau 1998

Conclusions

Was there a significant variation in soil physical conditions?

Yes !

Did these variations result into characteristic spatio-temporal flux patterns?

Yes !

Did a refined parameterization of plant funtional types in CLM result into more accurate flux calculations?

Yes !

Could crop models improve the calculation of flux patterns?

No !

To do

Improve the mathematical characterisation of crop physiological responses to the environment

Of immediate concern: Plant water-carbon relations and integration of stomatal regulation at the plant level