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Sensitivity and predictive uncertainty of the ACASA model at a spruce forest site

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EGER

Introduction

The Advanced Canopy-Atmosphere-Soil Algorithm (ACASA, Pyles et al. 2000), incorporating a third-order closure method to calculate turbulent transfer within and above the canopy, was used to model the turbulent fluxes of heat (H), water vapor (LE) and momentum as well as the CO_2 exchange (net ecosystem exchange NEE) within and above a spruce canopy at the FLUXNET-station Waldstein-Weidenbrunnen in the Fichtelgebirge mountains, Germany. Here, data of two intensive observation periods (IOPs) carried out in autumn 2007 and summer 2008 in the frame of the EGER project, are presented.

GLUE Methodology

Definition of parameter ranges
for 17 external and 10 internal input parameters

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Generation of random sets of parameters (θ_j)
from uniform distributions of parameter values (j=20000)

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Comparison of modelled and measured (Y) fluxes
to assess the performance of each run:
Calculation of likelihood measures ($L(\theta_j|Y)$)

↓

Coefficient of efficiency E

$$E = 1 - \frac{\sum (O_j - P_j)^2}{\sum (O_j - \overline{O})^2}$$

O : Observed data
P : Model simulated data

↓

Sensitivity graphs

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Cumulative frequency plots for best 10% runs
Determination of influential parameters
(Kolmogorov Smirnov test)

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Predictive uncertainty bounds

(Beven et al. 2000, Prihodko et al. 2008)

EGER IOP-1: September 2007

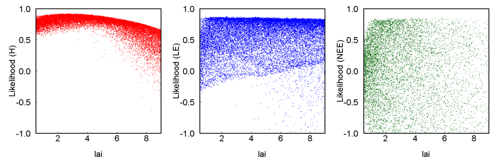

Figure 1: Sensitivity plots: coefficient of efficiency for sensible and latent heat flux and the NEE across the range of the leaf area index.

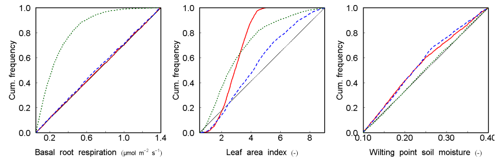

Figure 2: Cumulative frequency for the model parameters basal root respiration, leaf area index and wilting point soil moisture for the 10% best parameter sets for the index of agreement. The diagonal depicts a uniform distribution.

Table 1: Sensitive parameters for the latent and sensible heat flux and the NEE, ranked by the Kolmogorov-Smirnov coeffienct, for the 10% best parameter sets. Internal parameters for the plant physiology subroutine are printed in grey.

H	lai, r0l, jmax25, pr0, cm, drx, zmoi, pv0, vcmax25, q10l, ejmax, xldiam, iqe, tr0
LE	r0l, iqe, ejmax, lai, zmoi, cm, q10l, jmax25, cb, drx, vcmax25
NEE	r0r, r0m, lai, r0l, iqe, jmax25, q10l, vcmax25, ejmax, q10r, q10m

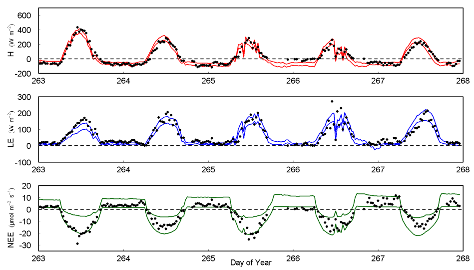

Figure 3: Predictive uncertainty bounds (5th and 95th quantile, solid lines) and observed values (black dots) for the sensible and latent heat fluxes and the NEE (20.-24. September 2007, best 10% of model runs).

EGER IOP-2: June/July 2008

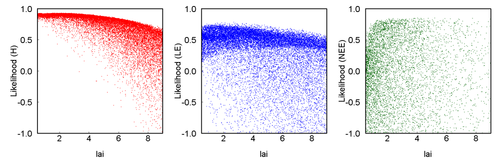

Figure 4: Sensitivity plots: coefficient of efficiency for sensible and latent heat flux and the NEE across the range of the leaf area index.

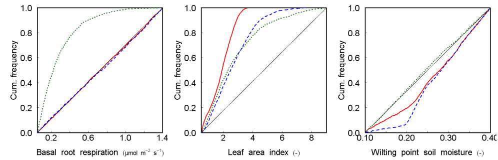

Figure 5: Cumulative frequency for the model parameters basal root respiration, leaf area index and wilting point soil moisture for the 10% best parameter sets for the index of agreement. The diagonal depicts a uniform distribution.

Table 2: Sensitive parameters for the latent and sensible heat flux and the NEE, ranked by the Kolmogorov-Smirnov coeffienct, for the 10% best parameter sets. Internal parameters for the plant physiology subroutine are printed in grey.

H	lai, drx, zmoi, pr0, hc, iqe, cm, r0l, jmax25
LE	lai, zmoi, r0l, iqe, drx, q10l
NEE	r0r, r0m, lai, r0l, iqe, q10l, q10r, q10m, jmax25, vcmax25, cm

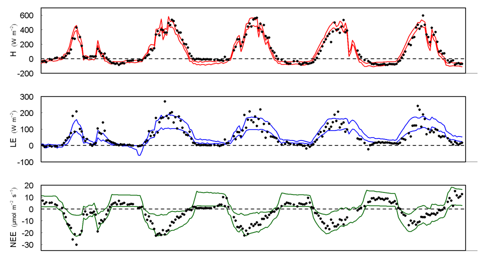

Figure 6: Predictive uncertainty bounds (5th and 95th quantile, solid lines) and observed values (black dots) for the sensible and latent heat fluxes and the NEE (28. June – 3. July 2008, best 10% of model runs).

Parameter sensitivity

Influential parameters for the ACASA model for two five day periods in September 2007 and June/July 2008 have been identified (Table 1 and 2). Among these are a number of internal parameters for the plant physiology subroutine, which stresses the importance to adjust these parameters for different species. Furthermore, the problem of parameter equifinality was seen in ACASA, similarly to other complex process based models, as the model was strongly sensitive to only a few parameters (such as the LAI, Figure 1 and 4).

Predictive uncertainty

Predictive uncertainty bounds encompassed the measured fluxes well for both IOPs (Figure 3 and 6). However, these uncertainty bounds were calculated for each flux individually. A comparison of the best 10% runs for the different fluxes indicated hardly any correlation. This means that a combined likelihood measure leads to uncertainty bounds that confine measured values less.

Seasonality of parameter values

The sensitivity analysis for two periods of different meteorological conditions (cold and wet autumn 2007, hot and dry summer 2008) revealed differences in the number and ranking of influential parameters. This suggests the need to seasonally adjust parameter values.

Structural weaknesses

The strong sensitivity of H to the LAI appeared to be linked to the lack of energy balance closure in the model – with increasing residuum the larger the LAI gets. For the NEE, soil respiration seemed to be the most imporatant process, due to a strong parameter interaction between the LAI and the basal soil respiration rates. These problems should be adresed in future ACASA versions.

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References:
Beven, KJ, Freer, J, Hankin, B, Schulz, K (2000) The use of generalised likelihood measures for uncertainty estimation in high order models of environmental systems. In: Fitzgerald, WJ, Smith RL, Walden AT, Young P (eds.), Non-linear and Nonstationary Signal Processing. Cambridge University Press, Cambridge, pp. 144–183.
Prihodko, L, Denning, AS, Hanan, NP, Baker, I, Davis, K (2008) Sensitivity, uncertainty and time dependence of parameters in a complex land surface model. Agricultural and Forest Meteorology 148: 268–287.
Pyles, RD, Weare, BC, Paw U, KT (2000) The UCD Advanced Canopy-Atmosphere- Soil Algorithm: comparisons with observations from different climate and vegetation regimes. Quarterly Journal of the Royal Meteorological Society 126: 2951–2980.

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