Evaporation over heterogeneous land surfaces – comparison between models and experiment

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1. Introduction

The major task of the project EVA-GRIPS (Regional **Eva**poration at **Gri**d/**P**ixel **S**cale over Heterogeneous Land Surfaces) funded by the German Ministry of Research and Education is the development of a concept to calculate area averaged evaporation and sensible heat fluxes over heterogeneous land surfaces for one pixel of different NWP models. Known concepts like the MOSAIC approach, the tile approach, the flux coupling approach and the application of effective parameters were implemented into standalone versions of the SVAT schemes TERRA of the Lokalmodell of the Deutscher Wetterdienst (DWD) and into that of the REMO/ECHAM model of the Deutsches Klimarechenzentrum (DKRZ).

The latent and sensible heat fluxes derived from the SVAT schemes are currently compared with measurements of the heat fluxes taken around the Meteorological Observatory Lindenberg (MOL) of the DWD during the three LITFASS campaigns 1998, 2002 and 2003. Area averaged heat fluxes are determined for the area around Lindenberg (Figure 1) between the 19th of May and the 17th of June 2003. Figure 2 shows the parts of the different land use classes at the area around Lindenberg.

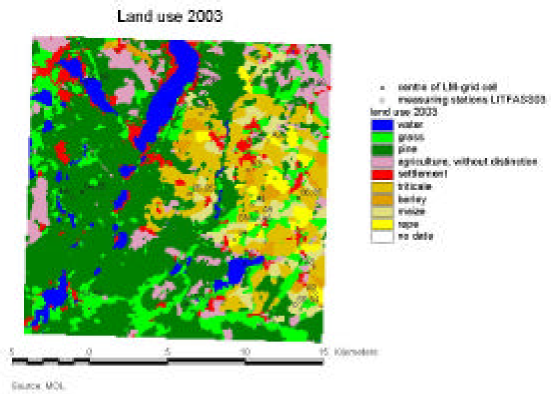

Figure 1: Area around Lindenberg (south-east of Berlin/Germany).

Here we show results obtained with the effective parameter approach: In order to simulate the heat fluxes with the SVAT schemes it is necessary to estimate appropriate values for all model parameters. Because not all parameters necessary to know for the input can be measured this approach allows to obtain the unknown parameters by minimizing objective functions describing the disagreement between the SVAT schemes and the measurements.

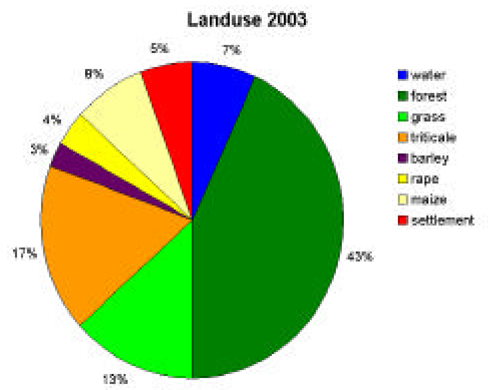

Figure 2: Land use classes of the LITFASS area.

2. Results

2.1. Calibration

To calibrate the SVAT schemes we applied the multi-objective shuffled complex evolution algorithm MOSCEM-UA [1] of the University of Arizona to obtain global minima of independent objective functions.
Here this algorithm is not only applied to the different classes of land use but also to the area averaged heat fluxes to estimate effective parameters for the whole area around Lindenberg which is used as example for one pixel of an NWP model.
Table 1 lists the optimized parameters for each class of land use together with their abbreviations and ranges.

		Unit	Range
RoughnessLength	RL	m	0.01 ... 0.8
Albedo	ALB	1	0.05 ... 0.35
MaxStomataR	MSR	s/m	250 ... 5000
VegetationRatio	VR	1	0.0 ... 1.0
LeafAreaIndex	LAI	1	1.0 ... 6.0
SoilHeatCapacity	SHC	$Jkg^{-3}K^{-1}$	500 ... 5000
FieldCapacity	FC	m	0.1 ... 0.9

Table 1: Optimized Parameters and their ranges.

The algorithm determines the set of pareto-optimal objective function vectors of rank R. A vector **x** of objective functions is said to dominate (i.e. has a lower rank than) another objective function vector **y** if an i exist for all $\mathbf{x}_i$ with $\mathbf{x}_i<\mathbf{y}_i$ and for all i $\mathbf{x}_i<=\mathbf{y}_i$ is true. $\mathbf{x}_i$ and $\mathbf{y}_i$ are the elements of **x** respectively **y**. The pareto-optimal objective function vectors of rank 1 are non-dominated. The pareto sets for all land use classes together with the pareto set for the area averaged heat fluxes are shown in figure 3: To determine the objective functions only data with higher quality (i.e. quality flag lower than 4) were used. As independent objective functions ***OF*** we used a modified Nash-Sutcliffe measure (optimum at 0) applied to the differences between the measured heat fluxes $\boldsymbol{Q_{obs}}$ and calculated heat fluxes $\boldsymbol{Q_{sim}}$:

$$OF = \frac{\sum_{i=1}^{N} \left(Q_{obs} - Q_{sim}\right)^2}{\sum_{i=1}^{N} \left(\overline{Q_{obs}} - Q_{obs}\right)^2}$$

The algorithm allows to optimize N independent objective functions parallel. Here is N=2 for the latent and sensible heat fluxes.

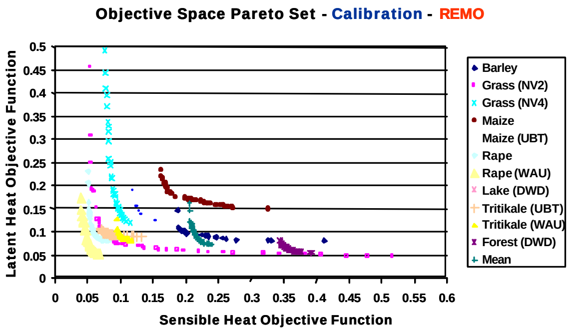

Figure 3: Objective space for the LITFASS 2003 parameter sets of the SVAT scheme of the REMO/ECHAM model with pareto rank 1 (calibration period).

As example, figure 4 shows the normalized parameter ranges for the pareto rank 1 set of barley compared with the SVAT scheme of the REMO/ECHAM model. It can e.g. be seen that the parameter leaf area index (LAI) and the maximum stomata resistance (MSR) vary over nearly the complete range within the best pareto set while the soil heat capacity (SHC) or the roughness length (RL) show smaller ranges.

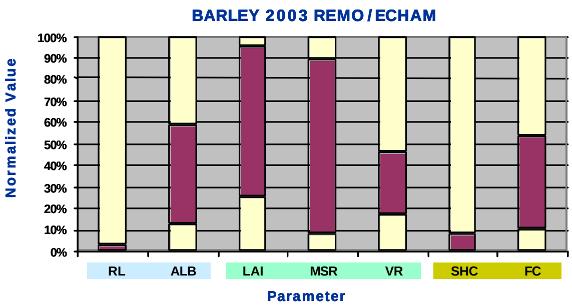

Figure 4: Normalized parameter ranges for pareto rank 1 sets for the measurements above barley compared with REMO/ECHAM. The parameter abbreviations are given in Table 1.

2.2. Validation

Figure 5 shows the objective space of the pareto sets with rank 1 for all classes of land use 2003 and the area averaged mean class applied to the validation period. The validation period is every 2nd day between the 19th of

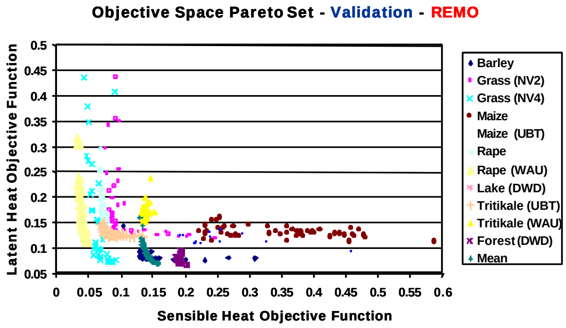

Figure 5: Objective Space for the validation period (every 2nd day between the 19th of May and the 17th of June 2003).

May and the 17th of June 2003. Similar results can be obtained by using the TERRA/LM model.

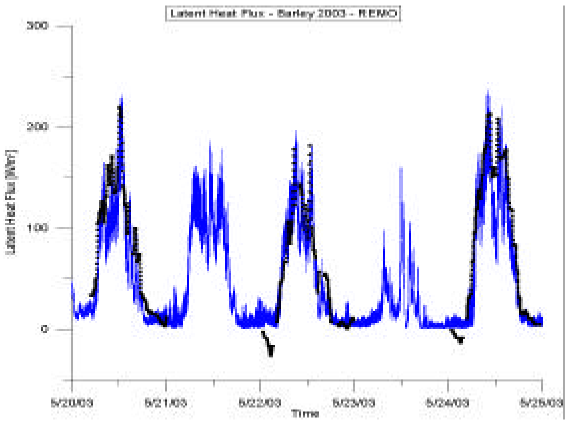

Figure 6: Latent heat flux measurements above barley taken during LITFASS 2003 and compared with the range for all parameter sets with pareto rank 1 (first three days of the calibration period).

Figure 6 shows the latent heat flux measurements above barley compared with the ranges between minimal and maximal latent heat fluxes as modeled with REMO/ECHAM for all parameter sets with rank 1. Similarly, Figure 7 shows the sensible heat fluxes.

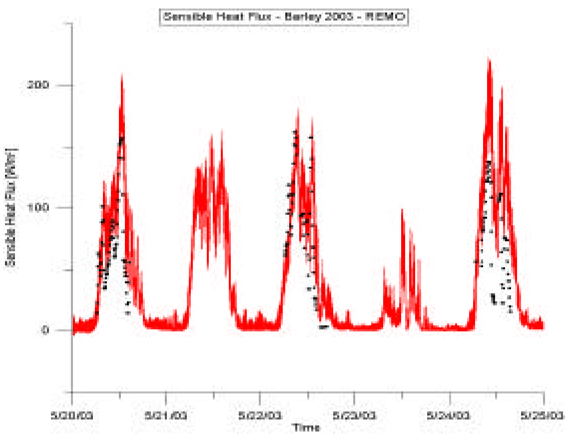

Figure 7: Sensible heat flux measurements above barley taken during LITFASS 2003 and compared with the range for all parameter sets with pareto rank 1 (first three days of the calibration period).

Reference:.

[1] J.A.Vrugt, H.V.Gupta, L.A.Bastidas, W.Bouten and S.Sorooshian: Effective and efficient algorithm for multi-objective optimization of hydrologic models, Water Resources Research, 39 (8), art. No. 1214, DOI 10.0129/2002WR001746