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Sensible and latent heat flux over natural bog vegetation

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Abstract

Goudriaan's crop model is tested for its ability to describe the energy balance of a natural bog vegetation. Data used to drive the model were collected during the summer of 1994. Model results were compared with field data obtained by means of the eddy correlation technique. The present study indicates that the model results are satisfactory as both sensible and latent heat fluxes are overestimated by 6% only. Furthermore, sensitivity analyses have shown that the model results are sensitive to the soil surface resistance to evaporation. Hence, there is a need to incorporate the soil surface resistance to evaporation as a function of time.

1. INTRODUCTION

Many physical and biological models have been developed to simulate the heat and mass exchange between arable crops and the atmosphere. Most of them were validated for different field crops in the past. Application of these crop models to natural vegetation will further identify areas of their strength and weaknesses under varying soil, vegetation, and climatic conditions. With this aim, in the present paper, Goudriaan's crop model [1] is tested for its suitability to describe the physical processes of a natural vegetation from a bog region.

2. MODEL, MATERIALS AND METHODS

The model formulated by Goudriaan [1] simulates the micro-weather within crops as a function of vegetation, soil, and boundary conditions. Feedback of vegetation and soil on their environment is included in the model. The partitioning of the absorbed radiant energy into sensible heat, latent heat, and photosynthesis is calculated using the energy balance equations [2, 3]. For details about the model, the readers are referred to Goudriaan's monograph [1].

The study area is located in a bog region of the northern part of The Netherlands. The dominating type of natural vegetation is grass locally known as Pijpestrootje (*Molinia Caerulea*) growing in irregular humps over the region. The soil of the area is waterlogged peat mainly formed due to decomposition of dead organic matter. The canopy and the boundary weather observations were carried out under the SLIMM project [4, 5] during the summer 1994. Two kinds of meteorological data were collected. An input set, to drive the model, includes wind speed, vapour pressure, air temperature at 4.0 m (reference level) above the soil surface and global as well as net radiation above the vegetation. In another set, to compare the model results, fluxes of sensible and latent heat were measured by the eddy correlation technique. The grass and soil physical parameters were taken either from the measured data from the field or from the available literature. Some major input parameters used to drive the model for the standard run are shown in Table 1.

Table 1
Grass and soil characteristics used in the model

Parameters	Unit	Value
Grass height	m	0.75
Leaf area index (LAI)	m^2m^{-2}	1.50
Average leaf width	m	0.005
Surface roughness (z_0)	m	0.07
Internal regulatory CO_2 concentration	vpm	240.0
External CO_2 concentration	vpm	350.0
Thermal conductivity of the top soil layer	$Wm^{-1}K^{-1}$	0.08
Volumetric heat capacity of the top soil layer	$Jm^{-3}K^{-1}$	$2.4*10^6$
Water stress in the soil	bar	-0.1
Soil surface resistance to evaporation (RESS)	sm^{-1}	500.0

Most of the area of the bog region was covered by the humps. The top layer of the humps, which constitute dead organic (grass) matter, was partially dry during the period of simulation. This partially dry layer of the dead grass on the humps reduced the water loss from the soil through evaporation. Therefore soil surface resistance to evaporation (RESS) was taken arbitrarily 500 sm^{-1} as input for the model. Measured data of the soil thermal conductivity, using the nonsteady-state probe method [6], were also used in this study. Further, a sensitivity analysis was done to judge the importance of the input soil and grass variables for the behaviour of the model. The model was run at different input values of the RESS: at 0 sm^{-1} to represent wet soil surface [1] and at 250 sm^{-1}, which could be possible due to occurrence of rainfall and dewfall over the bog region. Besides these the model was also run at different input values of LAI to see its influence in comparison to RESS for the same magnitude of variation.

3. RESULTS AND DISCUSSION

The model was run for two consecutive days (August 30 and 31, 1994). The weather conditions used as input to drive the model, are shown in Figure 1. The simulated energy balance over natural vegetation is presented in Figure 2. The temporal variation of measured and simulated fluxes of sensible and latent heat are shown in Figures 3 and 4. The root mean square error (RMS) of the simulated sensible heat flux equals 13.9 Wm^{-2}. The RMS is calculated using equation (1) in which H_{mi} and H_{si} are the measured and simulated

$$RMS=\left(\frac{\sum_{i=1}^{N}(H_{mi}-H_{si})^2}{N}\right)^{1/2} \tag{1}$$

sensible heat fluxes, respectively, at half an hourly intervals i, and N=96 is the number of half an hourly measurements. Similarly the RMS of the simulated latent heat flux equals 20.9 Wm^{-2}. The Regression line forced through the origin indicated that both sensible and latent heat fluxes were overestimated by about 6% (Figure 5 and 6).

The results of the sensitivity analysis are presented in Table 2. It was found that soil surface resistance to evaporation, RESS has much influence on latent and sensible heat fluxes [7].

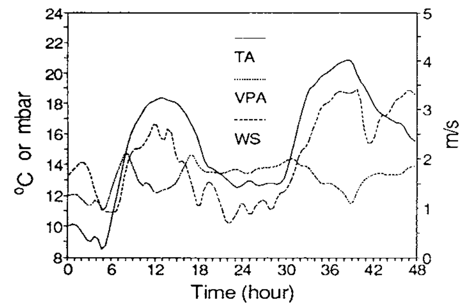

Figure 1. Boundary weather conditions used in the study. The scale for air temperature (TA), water vapour pressure in the air (VPA) are given on the left ordinate and for wind speed (WS) on the right ordinate.

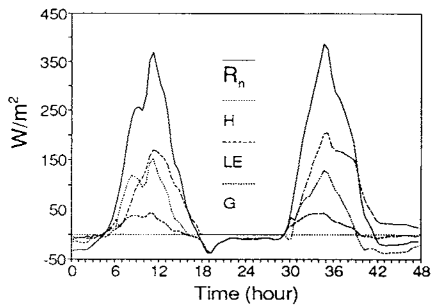

Figure 2. Net radiation used in the study (R_n) together with simulated sensible heat flux (H), latent heat flux (LE) into the air above the vegetation and soil heat flux (G) at 1 cm depth.

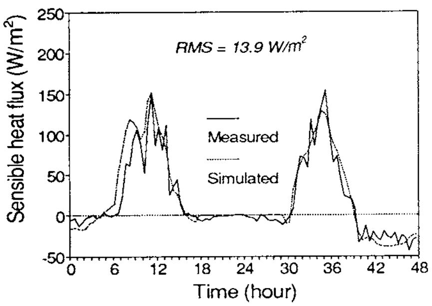

Figure 3. Variation of measured and simulated sensible heat fluxes over natural bog vegetation during two consecutive days.

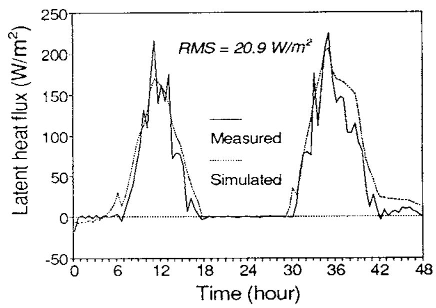

Figure 4. Variation of measured and simulated latent heat fluxes over natural bog vegetation during two consecutive days.

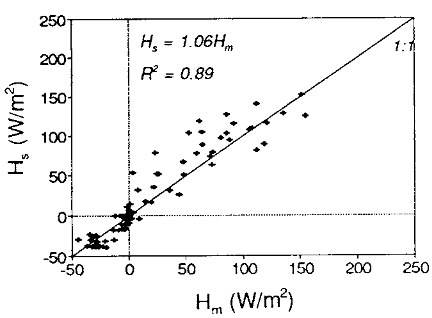

Figure 5. Measured sensible heat flux (H_m) versus simulated sensible heat flux (H_s). The linear regression line forced through the origin is $H_s = 1.06H_m$ (N = 96).

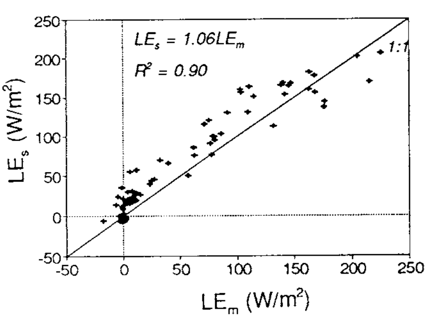

Figure 6. Measured latent heat flux (LE_m) versus simulated latent heat flux (LE_s). The linear regression line forced through the origin is $LE_s = 1.06LE_m$ (N = 96).

The 50% variation in RESS value is quite possible under peat soil situations of the bog region. Also, unlike grass parameters, the value of the RESS even can vary significantly within a day due to occurrence of rainfall or dewfall. Therefore, it is likely to get an improve model results with time variable of RESS. Obviously, an increase in LAI of grass caused a substantial increase in CO_2 assimilation.

Table 2
Influence of some parameters on daily fluxes. The change with respect to the standard run is indicated by the arrow

Variables	Unit	Standard	RESS		LAI	
		run	500→0	500→250	1.5→3.0	1.5→2.25
DNCO2	kg CO_2ha^{-1}	189.0	193.0	190.0	228.0	218.0
DNRAD	10^6Jm^{-2}	7.50	7.50	7.50	7.50	7.50
DLHF	10^6Jm^{-2}	4.69	7.78	5.39	5.41	5.14
DSHF	10^6Jm^{-2}	2.04	-0.75	1.40	1.34	1.59
DLHFB	10^6Jm^{-2}	1.51	5.29	2.35	1.11	1.31
DSHFB	10^6Jm^{-2}	1.30	-1.47	0.68	0.21	0.59
DSOILF	10^6Jm^{-2}	0.51	0.20	0.44	0.44	0.47

DNCO2 : Net CO_2 assimilation
DNRAD : Net radiation
DLHF : Latent heat flux above canopy
DSHF : Sensible heat flux above canopy
DLHFB : Latent heat flux at bottom
DSHFB : Sensible heat flux at bottom
DSOILF : Soil heat flux

4. SUMMARY AND CONCLUSIONS

Goudriaan's model simulated sensible and latent heat flux reasonably well over the natural grass in the bog region. It is likely that an incorrect value of soil surface resistance to evaporation may lead to an error in the simulated fluxes. Therefore, incorporation of soil surface resistance to evaporation as a function of time may further improve the model results, particularly in a case of a longer period of simulation.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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