ENERGETICKÁ BILANCE HORSKÉHO SMRKOVÉHO POROSTU

ENERGY BALANCE OF A MOUTAIN SPRUCE FOREST

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Abstract

Incident global radiation, net radiation and main energy budget components were measured in a Norway spruce stand at the Experimental Ecological Study Site at Bílý Kříž in the Moravian-Silesian Beskydy Mts. The aim of this study was to describe the energy balance diurnal course and to evaluate the efficacy of utilization of the incident global radiation in some selected processes running on the land surface.

Diurnal courses of the observed variables corresponded very well. All curves were rather smooth during May 27th, but during May 26th and 28th they were influenced by cloudiness. Net radiation had a typical diurnal period with positive values during the sunshine and negative ones during the night. Net radiation became positive one hour after the sunrise. In the evening, energy balance reached negative values as early as one hour before the sunset. Reflected global radiation accounted for approximately 13% of the incident global radiation, the net radiation about 72%, the sensible heat flux 35% and lastly the latent heat flux 14%. Net radiation was very well correlated with the incident global radiation. Pearson`s correlation coefficient (R^2) was of 0.99 during all three days.

Introduction

One of the most urgent problem dealing with global biosphere is an increasing threat of Global Climatic Change. In this way, forest ecosystems represent a very important part of the biosphere because of their area, structure and longevity. Therefore, there is a need to evaluate if the forest stands could be a regulator of the energy balance and a need to study energy and substance fluxes between the forest stand and the atmosphere boundary layer (BLA) as well. Relations between the land surface and the BLA are reciprocal, they have an interactive character and are more intensive if a vegetation cover is present (Hurtalová et Matejka 1999).

Energy incoming from the Sun is the fundamental source of energy for processes running on the land surface. A part of this energy is absorbed by the surface, while another

part is reflected back to the atmosphere. Land surface itself is a source of long-wave radiation. Difference between the radiation absorbed by the surface and the net terrestrial radiation is called radiation balance (R). The energy of the radiation balance is used for the evaporation from the land surface and for some heat transfers to the soil and to the atmosphere. The equation of the energy balance describes this process:

$$R=H+LE+P$$

where R is the radiation balance, H is the sensible heat flux, LE is the latent heat flux and P is the surface soil heat flux.

In the conditions of the Czech Republic mountain forests are the most numerous. Therefore, the Laboratory of Ecological Physiology of Forest Trees observe the energy budget component of a young spruce monoculture at the Experimental Ecological Study Site (EESS) at Bílý Kříž. Likewise for this reason we tried describe and estimate energy fluxes between the spruce stand and the atmosphere boundary layer which is assessed to be the main aim of this work. We used a direct measurement, where the methodology description for the flux measurement is defined in Aubinet 2000.

Material and methods

The results presented in this paper come from some measurements carried out in a Norway spruce stand (*Picea abies* [L.] Karst.) at the EESS at Bílý Kříž during the choosing days 26^{th}-28^{th} May 2000.

This Study Site is situated on the top part of the Moravian-Silesian Beskydy Mountains. The geographical position of EESS is given with the following co-ordinates 49° 30''17' North, 18°32''28' East and an altitude of 908m above the sea level. Climatic conditions are represented by a mean annual air temperature of 4,9°C, a mean annual amount of precipitation of 1100mm and a mean annual relative air humidity of 80%. Measurements of energy fluxes were carried out on a hillside with a slope of 13° and with a SSW orientation. The stand was 19-year-old (planted in 1981 with four-year-old seedlings), had a density of the stand was 2500 trees per ha. Trees average height at the beginning of the 2000 vegetation season was of 7,5m ± 0,1.

Energy fluxes measurement was performed with a eddy-covariance system Edisol (University of Edinburgh, UK). This system measured windspeed, wind direction, air temperature, concentration of CO_2, water vapour and other characteristics. Fluxes of CO_2, H_2O, momentum, sensible and latent heat are calculated from obtained values. The system consisted of a sonic anemometer Solent A1012R (Gill Instrument, Lymington, UK) situated at

a height of 12 m above the ground surface, of an infrared gas analyser LI-6262 (LI-COR, Lincoln, Nebraska, USA) and of an EdiSol software (University of Edinburgh, UK) (Moncrieff et al. 1997).

Net radiation was measured thanks to two Tube Net Radiometers (Delta-T devices, UK). These radiometers were placed at 12m high above the ground level. Distance between these two radiometers was about 50m. The average values of these two instruments are presented here.

Global solar radiation, and reflected solar radiation were measured with a solarimeter TSL at 12m high above the ground surface. To describe the climatic characteristics of the spruce stand, air temperature and absolute humidity were measured with a sensor RHA1 (Delta-T devices, UK) at the following heights 2, 6, 7, 9 and 12m (for a better lucidity, only data recorded by the sensor at 2, 7, and 9m were used). The land surface temperature was measured at 5cm in depth with a thermistore Pt1000 (HIT Uherské Hradiště). All values were expressed as an average over half an hour.

Results and discussion

The day May 27th was almost clear, while the days May 26th and 28th were half-covered. The daily maximums of global radiation reached the values of 784, 771 and 736 W.m^{-2}. The mean value of air temperature during these three days was of 17,0°C. The lowest temperature was measured May 28th at 4:30 a.m. (9,8°C), and the highest at 15:30 p.m. in May 27th (22,5°C). The absolute humidity of air for all presented days varied between 6,5 and 11,8 g.m^{-3}. The course of air temperature and absolute air humidity is shown in Fig.1.

One part of the energy absorbed by the forest is released to the atmosphere as a long-wave terrestrial radiation, when the remaining part is mainly used for the sensible and latent heat flux and for the surface soil heat flux. The energy absorbed by the forest (expressed as a difference between the incident and the reflected global radiation), the net radiation and the main energy budget component are presented in Fig.2. The depicted variables course fitted together very well. All curves were rather smooth during May 27th, but during May 26th and 28th they were influenced by cloudiness. Net radiation had a typical diurnal period with positive values during the sunshine while negative ones occurred during the night. Net radiation was negative at the sunrise and sunset moment, it achieved positive values approximately one hour after and one hour before daybreak. This phenomenon was especially noticeable for May 27th.

The use efficiency of the incident global radiation is shown in Fig. 3 and in Tab.1. Approximately 13% of the incident global radiation was reflected back to the atmosphere during the three described days. The net radiation amounted to about 72% of the global radiation, the sensible heat flux represented about 35% and latent heat flux 14%.

Tab.1: Proportion of the diurnal (respective three days) sum of the reflected global radiation (rGR), the net radiation (NR), the sensible heat flux (H), the latent heat flux (LE) and the sum of the sensible and latent heat flux (H+LE) to the diurnal (respective three days) sum of the incident global radiation (iGR).

	rGR/iGR (%)	NR/iGR (%)	H/iGR* (%)	LE/iGR (%)	H+LE/iGR (%)
26.5.2000	13,9	71,8	39,3	16,4	55,7
27.5.2000	13,3	69,9	34,3	12,3	46,7
28.5.2000	13,6	74,6	32,6	14,6	47,3
26.-28.5.2000	13,5	72,0	35,0	14,2	49,2

Net radiation was very well correlated with the incident global radiation. The Pearson`s correlation coefficient (R^2) was of 0,99 during all three days. Day May 27th was chosen to describe the situation during a typical sunny day. The course of the incident global radiation, the net radiation and the temperature at a depth of 5cm during this day is shown in Fig. 4, The change in the land surface temperature was negligible. The energy flux between the land surface and the atmosphere especially caused a change in air temperature.

Fig.1: The course of air temperature (red line) and absolute humidity (green line) above the spruce stand in the EESS at Bílý Kříž during 26th-28th May 2000.

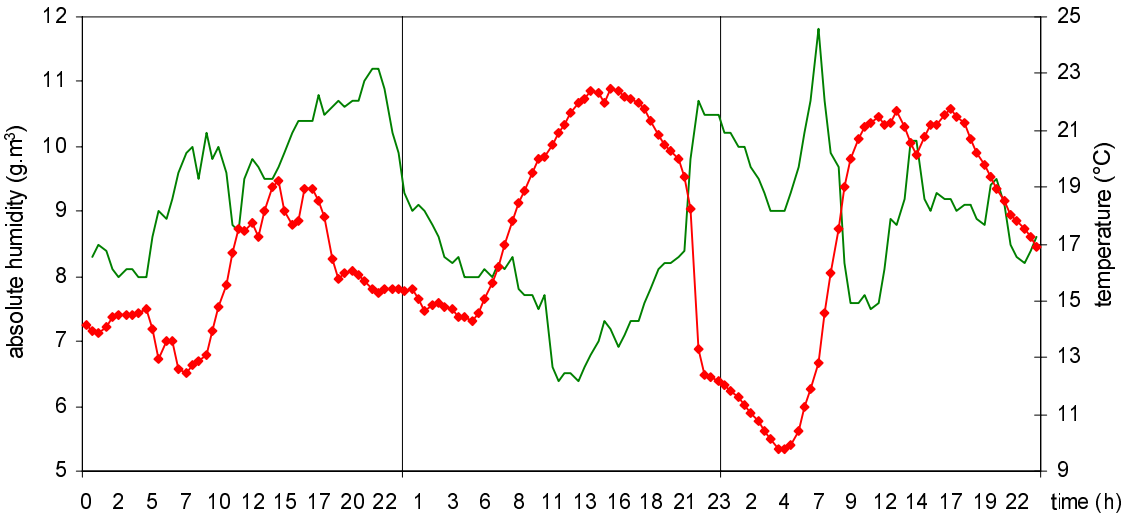


Fig.2: The course of the incident global radiation (iGR), difference between the incident and the reflected global radiation (iGR-rGr), net radiation (NR), sensible heat flux (H), latent heat flux (LE) above the spruce stand in the EESS at Bílý Kříž during 26th-28th May 2000.

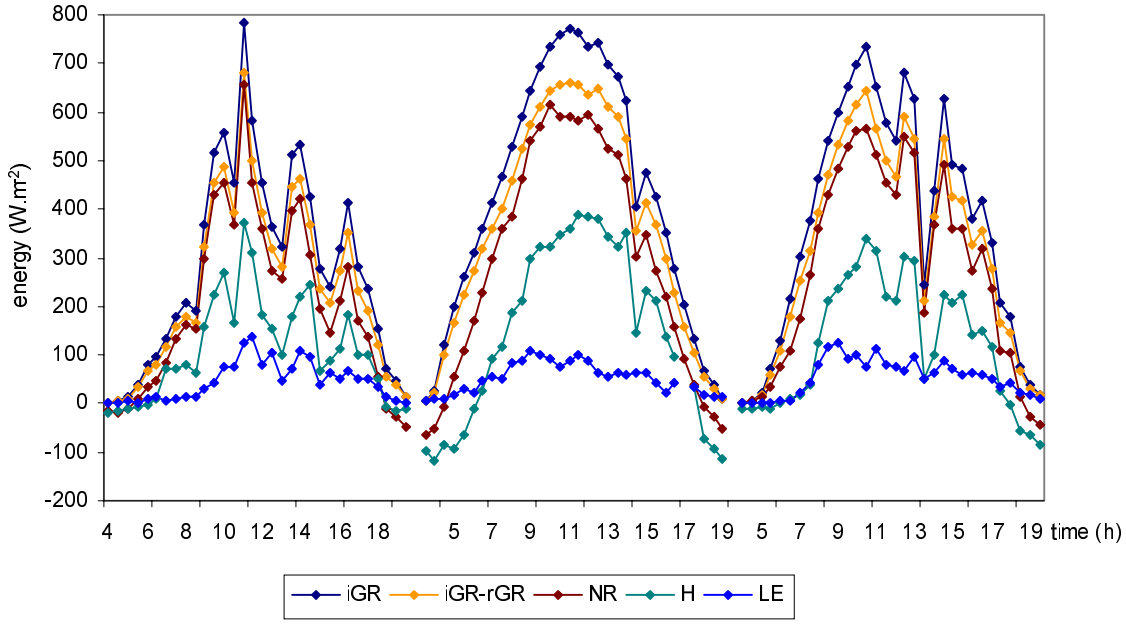


Fig.3. The proportional course of net radiation (red line), the sum of the sensible and the latent heat flux (violet line), the sensible heat flux (orange line), latent heat flux (green line) and the reflected global radiation (blue line) from the incident global radiation observed above the spruce stand in the EESS at Bílý Kříž during 26th-28th May 2000 (all line were smooth using the moving average 5).

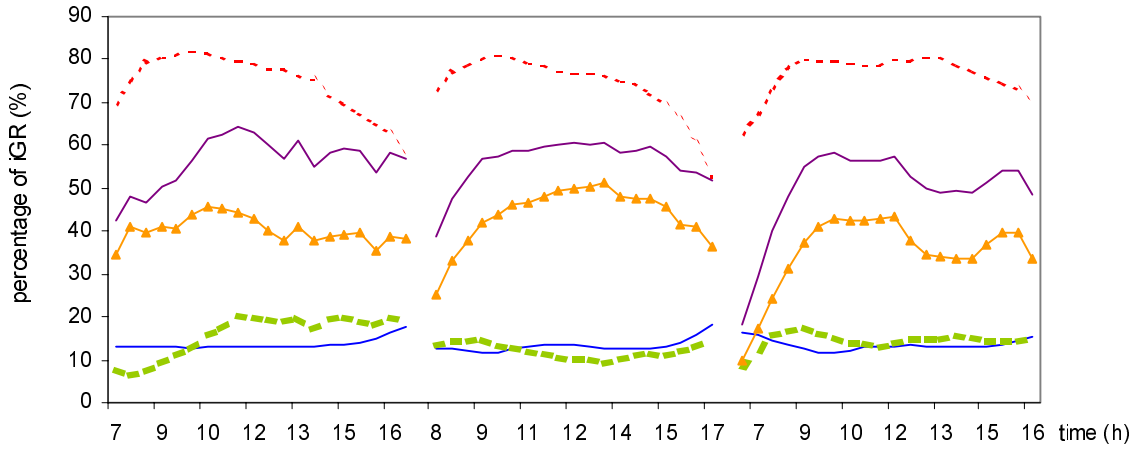
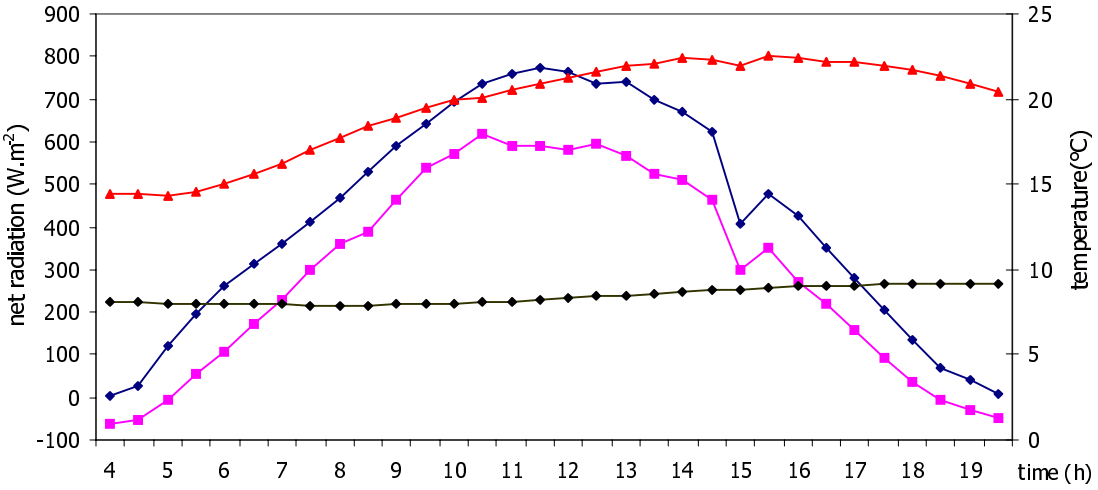


Fig. 4: The courses of the incident global radiation (blue line), the net radiation (violet line), the air temperature (red line)and the temperature at a depth of 5 cm (black line) observed above the spruce stand in the EESS at Bílý Kříž during 26th-28th May 2000.



Conclusion

The courses of the global radiation, net radiation and the main energy budget components corresponded very well. All curves were rather smooth during May 27th, but during May 26th and 28th they were influenced by cloudiness. The net radiation became positive one hour after sunrise. In the evening, energy balance already achieved negative values one hour before sunset. Reflected global radiation amounted to approximately 13% of the incident global radiation, the net radiation about 72%, the sensible heat flux 35% and latent heat flux 14%. The net radiation correlated very well with the incident global radiation. The Pearson`s correlation coefficient (R^2) was of 0,99 for all three days.

Souhrn

Globální sluneční záření, celková radiační bilance a hlavní složky energetické bilance byly sledovány v mladé smrkové monokultuře na Experimentálním ekologickém pracovišti na Bílém Kříži v Moravskoslezských Beskydech. Hlavní úkolem tohoto příspěvku bylo popsat denní chod energetické bilance a zhodnotit efektivnost využití dopadající radiace pro vybrané procesy probíhající na zemském povrchu.

Denní chody sledovaných veličin se poměrně dobře shodovaly. Dne 27.5.2000 byly všechny křivky poměrně hladké, na rozdíl od 26.5 a 28.5. 2000, kdy byly ovlivněny oblačností.

Celková radiační bilance měla charakteristický chod s kladnými hodnotami v období insolace a se zápornými v nočních hodinách. Radiační bilance nabývala kladných hodnot přibližně hodinu po východu Slunce. Ve večerních hodinách bilance dosahovala negativních hodnot zhruba hodinu před západem Slunce.

Z dopadajícího globálního slunečního záření tvořilo odražené globální sluneční záření přibližně 13%, radiační bilance 72%, turbulentní tok tepla 35% a latentní tok tepla 14%. Hodnoty celkové radiační bilance a dopadajícího globálního záření spolu dobře korelovaly. Pearsonův korelační koeficient (R^2) ve všech třech dnech dosáhl hodnoty 0,99.

Klíčová slova

Celková radiační bilance, energetická bilance, turbulentní tok tepla, latentní tok tepla.

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