available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/agrformet

Spatial variability in soil heat flux at three Inner Mongolia steppe ecosystems

Changliang Shao[a,b,*], *Jiquan Chen*[a,c], *Linghao Li*[a], *Wenting Xu*[a], *Shiping Chen*[a], *Tenney Gwen*[c], *Jianye Xu*[a,b], *Wenli Zhang*[a,d]

[a] *Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, China*
[b] *Graduate University of Chinese Academy of Sciences, Beijing 100049, China*
[c] *Department of Environmental Sciences, University of Toledo, Toledo, OH 43606, USA*
[d] *College of Chemistry and Life Sciences, Three Gorge University, HuBei 443002, China*

ARTICLE INFO

Article history:
Received 20 October 2007
Received in revised form
14 April 2008
Accepted 18 April 2008

Keywords:
Energy balance
Soil heat flux
Available energy
Eddy-covariance
Grassland
Inner Mongolia

ABSTRACT

Closing the energy budget at flux measurement sites is problematic, even when the fetch extends over flat, homogeneous surfaces with low vegetation cover. We used the residual energy balance and ordinary least square (OLS) linear regression methods to quantify spatial variability in soil heat flux contributing to energy balance closure (EBC), by deploying a mobile energy system within the footprints of three Eddy-covariance towers located in the steppe of Inner Mongolia, China. The EBC at the study sites had a daily average residual of 8–19 W m^{-2} with OLS slopes of 0.83–0.96. The EBC was better achieved at the wet site than at the dry site. The spatial variability in soil heat flux was 48 W m^{-2} (13% of R_n) during the day and 15 W m^{-2} (34%) at night, with an average of 29 W m^{-2} (24%) across the three sites. A 9% OLS slope difference due to this variability was recorded from our eight plot measurements. A large amount of missing energy (110 W m^{-2} at peak) could occur with decreasing OLS slope of 23% across the three grassland sites when soil heat flux is not taken into account. In particular, heat storage in the top soil layer not only influenced the magnitude of EBC, but also adjusted soil heat flux to match the 'truth schedule'. Heat storage in the top soil layer comprised half of the soil heat flux when the heat flux plate was deployed at a depth of 30 mm. If this part of heat storage was neglected, the residual of EBC would increase as large as 60 W m^{-2} with OLS slope decreasing 9%. Comparing them with the multiple-location soil heat flux measurements, the single-location measurements from near the Eddy-covariance towers obtained a slightly better EBC with the OLS slope increasing by 4%.

1. Introduction

Closing the energy budget at flux measurement sites is problematic, with up to 30% of energy unaccounted for even when the fetch ideally extends over flat, homogeneous surfaces with low vegetation cover (Mahrt, 1998; Stannard et al., 1994; Twine et al., 2000; Wilson et al., 2002). Failure to close the energy balance at a particular site may imply that some or all of the scalar fluxes have been inaccurately measured using the Eddy-covariance (EC) method (Baldocchi et al., 2001; Dugas et al., 1991; Mahrt, 1998; Turnipseed et al., 2002; Twine et al., 2000; Wilson et al., 2002). Malhi et al. (2004) suggested that, apart from sampling error, inadequate spatial sampling of soil heat flux is a possible explanation of the failure to close the energy budget.

* *Corresponding author at*: Institute of Botany, Chinese Academy of Sciences, No. 20 Nanxincun, Xiangshan, Beijing 100093, China.
E-mail address: zkyscl@ibcas.ac.cn (C. Shao).

0168-1923/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.agrformet.2008.04.008