J12.4 COMPARISON OF OBSERVED AND MODELED SURFACE FLUXES OF HEAT FOR THE VOLTA RIVER BASIN

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1. INTRODUCTION

During the past decade land-surface-models (LSM) have improved continuously, especially with the help of field experiments. However, evaluation is still needed for semi arid regions like West Africa.
Therefore we evaluate a land-surface-model with the help of Large Aperture Scintillometer (LAS) measurements for three different research sites in Ghana. We chose the LAS because the method is relatively robust and the method yields area-averaged fluxes over complex terrain.
The focus is on evaluating the modeled surface heat flux H against data collected during the dry season from November 2001 until March 2002. Measurements during that period show low soil moisture contents and high sensible heat fluxes.
As a first step, a reference model configuration is used and compared to the LAS measurements. In a second step the LSM is adapted to the conditions in the Volta River Basin. The results from the adapted model are again compared with LAS measurements.
It is shown, that LAS measurements are a precise and robust means to measure sensible heat flux.

2. THE GLOWA-VOLTA DATA SET

All measurements are part of long-term observations of the water- and energy balance in the Volta Basin within the GLOWA-Volta project. GLOWA-Volta is a multidisciplinary effort to study the physical and socio-economic determinants of the hydrological cycle (van de Giesen et al, 2001).
The micrometeorological data used in this study are based on measurements from meteorological stations and LAS measurements in Tamale (9° 29' N, 0° 55' W), Navrongo (10° 55’ N; 1° 02' W) and Ejura (7° 20' N; 1° 16' W). The three sites show major differences concerning the vegetation, soils, land use, slopes and also climate.
Each site is equipped with one LAS. Each LAS consists of a transmitter emitting electromagnetic radiation towards a receiver.
The emitted radiation is scattered by the turbulent medium in the path. The variance of intensity of received radiation is proportional to the refractive index of air (C_n^2). At the used wavelength (940nm) C_n^2 is mostly sensitive to temperature fluctuation (C_T^2). Sensible heat flux is calculated from C_T^2 using Monin-Obukhov similarity theory. For a detailed description of the LAS technique see for example de Bruin et al, (1995).
The meteorological stations measure the temperature, humidity and global radiation at a reference level z = 2m. Wind speed and direction are measured at eight-meter height. Net radiation is measured directly. Additionally, surface observation for soil heat flux and precipitation are recorded. In Tamale, soil moisture and soil temperature measurements are part of the standard observation. For the two other sites they are recorded on a weekly basis. All quantities are averaged for ten-minute intervals.

3. MODEL DESCRIPTION AND PARAMETER ESTIMATION

The LSM used is the Oregon-State-University-Land-Surface Model (OSU LSM), also known as the Coupled Atmospheric boundary layer-Plant-Soil, or CAPS model. A full description can be found in Chang et al, (1999).
The model is used in a stand-alone mode to concentrate on the evaluation of the land surface processes for the specific region. It is driven by the prescribed atmospheric forcings. Because the current forcing data provide no longwave radiation, it is calculated using air temperature and relative humidity. The time step for integration is set to ten minute according to the measured quantities.

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The ***reference*** model is initialized using interpolated soil moisture and soil temperature observations. The bottom boundary soil temperature is set to the annual 2-m air temperature. Values for soil type, vegetation type, albedo and green vegetation fraction were obtained from NCEP. The soil- and vegetation-class dependent parameters are also adopted from the original NCEP configuration. The leave area index (LAI) is set to 4.0 across all sites.

For the ***adapted*** configuration some important changes are made. The monthly albedo for all sites is estimated to be 0.23. Satellite derived LAI is used on a monthly basis, different for each site. For roughness length z_0 for momentum, the same values are used as for calculating sensible heat flux from the LAS measurements. The changed values are given in **Table 1**. The Zilintinkevich coefficient used in the model for controlling the ratio of the roughness length for heat to the roughness length for momentum stays unchanged.

Table 1

Parameters	*Reference*	*Adaption*
Albedo α	*0.14 – 0.17*	*0.23*
LAI	*4.0*	*1.0 – 2.0*
z_0 *for momentum*	*0.835 m*	*0.1 – 0.2 m*
Bottom T.	*26.1 °C*	*26.1 °C*
Total soil depth	*2 m*	*2 m*

Table 1. Important parameters for the Reference and the adapted model.

4. RESULTS AND DISCUSSION

Sensible heat flux derived from the different LAS is compared with the model output from the reference setup and the adapted setup for daytime values. First we focus on evaluating the sensible heat flux for single cloudy days, to show exactly the difference between measured and modeled results. Secondly we compare longer periods to show the overall robustness of model and measurements.

4.1 Tamale Research Site

The site is characterized by mainly grassland with some trees, with a maximum height of six to eight meter. The landscape is hilly. The LAS is installed on two hills with a distance in between of about 2420 m. The weather station is installed next to the receiver.

In **Figure 1**, a comparison between measured sensible heat flux and sensible heat flux from the reference model is plotted for the 2nd of December 2001. Large differences in sensible heat flux up to 50 W m^{-2} appear during noon. Also net radiation is modeled not correctly (not shown here).

Figure 2 shows a comparison of measurements and adapted model for sensible heat flux. The modeled and measured values agree very well, only in the morning and during noon there are small differences. That is also the case for net radiation.

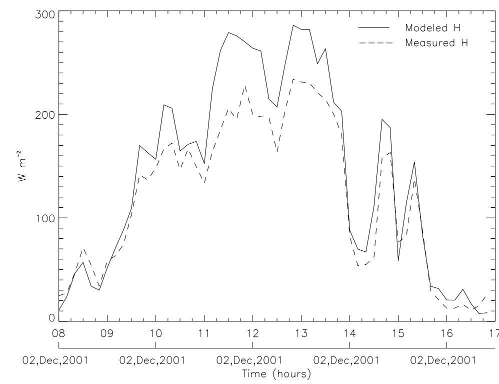

Figure 1. Reference modeled and measured sensible heat flux H for a cloudy day (2nd of Dec.) in Tamale.

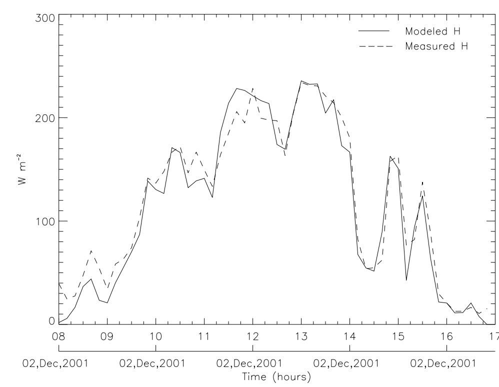

Figure 2. Adapted modeled and measured sensible heat flux H for the same day in Tamale.

The comparison between the reference model and measurements for a 20-day period in December shows the same trend as for the single day. The model tends to overestimate the sensible heat flux (y = 1.31 x, R^2 = 0.93). The comparison between adapted model and measurements are shown in **Figure 3**. The model performs better but for higher sensible heat fluxes the model still tends to overestimate sensible heat flux by about 10%.

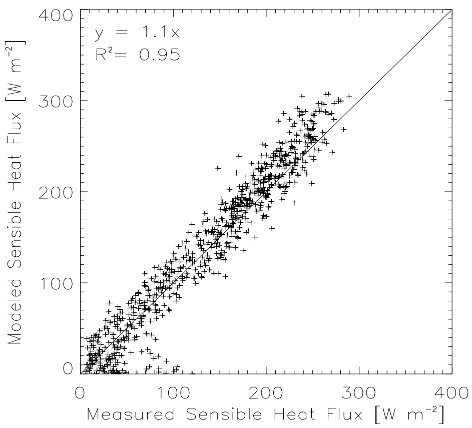

Figure 3. Comparison of modeled and measured sensible heat flux H for 20 days in December.

4.2 Navrongo Research Site

The site is located in northern Ghana. The area is characterized by extensive land use during the wet season. During the dry season it is mainly characterized by bare soil. The landscape is nearly flat. Transmitter and receiver are installed with a distance between of 1040 m.

Figure 4 shows the daily course for the reference modeled and measured sensible heat flux. For this site the reference model is underestimating sensible heat flux and overestimating net radiation. Especially in the morning and during midday appear differences with more than 50 W m^{-2}. The adapted model (**Figure 5**) shows smaller differences in sensible heat flux compared to the measured values. The peak after noon is still not modeled correctly. The net radiation is still overestimated.

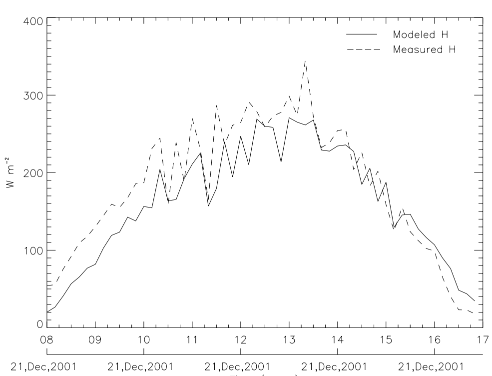

Figure 4. Reference modeled and measured sensible heat flux H for a cloudy day (21st of Dec.) in Navrongo.

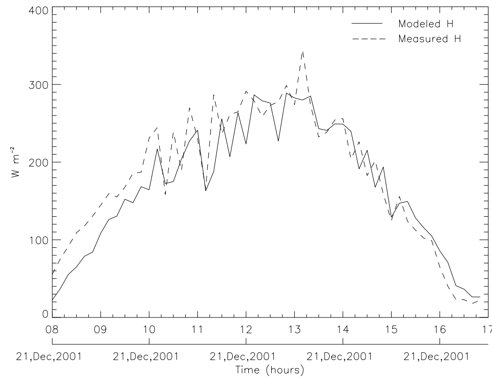

Figure 5. Adapted modeled and measured sensible heat flux H for the same day in Navrongo as Figure 4.

The comparison between reference model and measurements from the 20th of December until the 15th of January shows, that the model tends to underestimate sensible heat flux also on a larger time scale (y = 0.67 x, R^2 = 0.85). With the adapted setup the model performs better (y = 0.76 x, R^2 = 0.92).

4.3 Ejura Research Site

The site in Ejura is the most tropical site. Here the transmitter and the weather station are located in a cashew orchard. The receiver is located at the edge of a forest. The path in between is about 2030 m. It is a very heterogeneous terrain. On the transmitter site the vegetation consists of cashew trees and in between maize. On the receiver side there are bushes and trees and small swamps, but nearly no agriculture.

The results for the reference setup concerning sensible heat flux show already a small difference between modeled and measured values.

With the adapted setup the difference between modeled and measured fluxes are as small as for the other two sites.

Single peaks, due to clouds, are not modeled as well as for the other sites. This explains the lower correlation (R^2 = 0.81 for the reference model; R^2 = 0.85 for the adapted model). Here appears the same problem as in Navrongo; the net radiation is still overestimated.

On a larger time scale (6th of Feb. – 6th of Mar.) the reference model also tends to underestimate the sensible heat flux (y = 0.7 x). The adapted model also performs better (y = 0.75 x).

5. CONCLUSIONS

Our goal in this study was to evaluate a state-of-the-art LSM with LAS data during the dry period in the Volta River Basin. It is shown that after some small but important adjustments the model performs reasonable for sensible heat flux.

Further on we demonstrated, that LAS measurements over different surfaces give reliable estimates of sensible heat fluxes under dry conditions for different terrains and different length scales.

In future research we will focus on deriving fluxes of both H and L_vE from LAS also during the vegetation-growth-period to evaluate the used model for different conditions and for longer integration periods.

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