AN APPROACH FOR THE ESTIMATION OF SOIL HEAT FLUX IN ANTARCTIC REGION DURING SUMMER PERIOD

(Enfoque para la estimación del flujo de calor del suelo en la región de la Antártida durante el período de verano)

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Introduction

The energy coming from the Sun plays an important role in the climatic system as a whole, more specifically in the Earth energy balance. One of the energy term presents in this balance is the soil heat flux, which is an important component of surface energy, mostly in regions with arid, bare or thinly vegetated soil surfaces (Anandakumar et al. 2001). The soil heat flux is comprehended as the heat exchanged occurred between different depths into the soil, which both present different values of temperature (Bhumralkar, 1975).

Accuracy in estimative of soil thermal properties is very important for numerical modelling studies, since the heat sources affecting the atmospheric systems is the exchange of sensible and latent heat between the surface and atmosphere. The direction of these energy fluxes is primarily settled by the thermal conditions of the ground and the adjacent air (Bhumralkar, 1975). However, such estimates are not easily available, especially in such places as Antarctic region, which offers extreme climatic conditions for measurements in situ and heterogeneity in the surface properties.

Prosek et al. (1998) showed in a study about the components of energy balance budget in a vegetation oasis at Polish Station (Henryk Arctowski), King George Island, South Shetland Islands. The study was taken in summer season of 1994/1995 and they highlighted the influences of the energy balance on the temperature conditions of the soil substrata in the Antarctic region. They verified that there is a rapid reaction of the soil temperature to the radiation balance and sensible heat flux in 5 cm depth. In addition, the surface layer conditions and soil substrate play important roles to the habitat of the Antarctic vegetation oasis, which the results can be interpreted in pedological or botanical studies applied to this type of environment.

The study of the soil heat flux in an Antarctic region is beyond a contribution to the forecast numerical models. A better improvement of the important variable in the energy balance, contributes to understand the great environment to the Antarctic vegetation and its permanence in this region. Thus, this work proposes to evaluate a method of hysteresis to estimate the soil heat flux and compare with direct measures in Ferraz Station (EACF - 62°05’07” S, 58°23’33” W, 20 m about mean sea level) during summer season (Dec-Jan-Feb-Mar, DJFM) of 2013/2014. The data used in this work refers to the ETA Project (financial support by CNPq and INCT-APA).

Methodology

The measurements was taken from instruments installed in the EACF, located in the King George Island, which is part of the South Shetland Islands in Antarctic Peninsula.

The data used in this study was collected *in situ* during December 2013 to March 2014 (summer season - DJFM).The net all-wave radiation (R_n) data was obtained from a (NRLite2) installed in a micrometeorological tower (3.4 m of height), while the soil heat flux (G) was measured using Hukseflux – HFP01, 0.05 m depth with time response of 4 minutes. The sampling frequency was stored as 5 min average by a datalogger (CR5000, Campbell Scientific Inc.) using the local time (- 04 UTC) as standard time. The instruments installed were connected to this datalogger, which was connected to a laptop inside the Meteorology laboratory, that is responsible for transmit the data instantly to the Air-Sea Interaction Laboratory in IAG/USP.

Sometimes G measurements is not available due to difficulties encountered with observational measurements, and for that reason, empirical relationships between G and R_n can be used to obtain G. Following this concept, Grimmond et al. (1991) proposed an indirect method called as the Objective Method of Hysteresis (OHM to estimate G through values of R_n. The OHM model is based on the following expression:

$$G = a_1 R_n + a_2 \frac{\partial R_n}{\partial t} + a_3$$

where $\frac{\partial R_n}{\partial t}$ is the temporal variation of R_n at the surface, discretized in time here as $\frac{\partial R_n}{\partial t} = 0.5\ (R_n^{t+1} - R_n^{t-1})$, and a_1, a_2, and a_3 are empirical coefficients related to the response of the surface properties due to Solar energy. The coefficients play different role in the equation: a_1 is dimensionless and indicates the intensity of the relation between Rn and G; a_2 [s] shows the magnitude of hysteresis, presenting the direction and the degree of the phase relationship between R_n and G. At the end, a_3 [Wm^{-2}] is term of interception that indicates the extent to which negative values of G occurs before Rn initiates to become negative (Grimmond and Oke, 1991; Ferreira et al., 2013).

In the literature, the OHM model was mainly applied for urban areas and the coefficients are determined based on the land use classification and theirs values are shown as tables in many studies, as can be seen in Grimmond and Oke (1999), Meyn and Oke (2009), etc. However, for the EACF region, it is the first time that this method is applied and the values proposed for urban areas are not valid for the region studied here. For that reason, in this work are proposed coefficients to estimate G in this region for summer period.

The better coefficients found for the summer period 2013/2014 in EACF are shown in Table 1.

Table 1: Monthly coefficients of the OHM method for summer period 2013/2014 in EACF.

Month	**Coefficient**		
	a_1	**a_2**	**a_3**
December	0.17	-0.09	10.5
January	0.13	-0.03	11.6
February	0.12	-0.1	6.0
March	0.1	-0.068	4.7

Results and discussion

During December and January, the observational values of G presented high diurnal variation (Fig 1a). This G high amplitude is related with the more energy available during these months (Fig. 1b), with a daytime period around 9h - more than in the lasts months of the summer period (Feb and Mar). In addition, more ice is presented over the bare soil during the latest month of the summer period in this region.

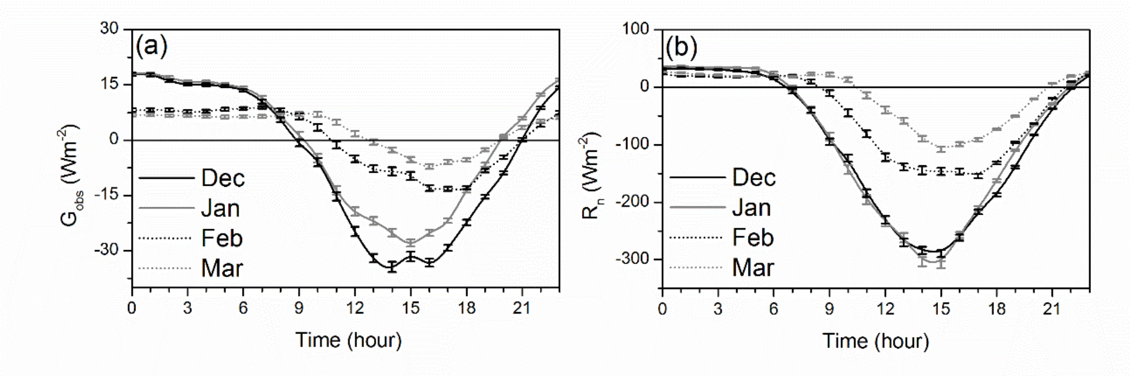

Figure 1. Average diurnal variation of (a) soil heat flux (G_{obs}) and (b) net all-wave radiation (R_n) for summer period (DJFM) of 2013/2014. The vertical bars indicate the statistical error.

The OHM model presented good agreement with the G observed diurnal variation values during summer period of 2013/2014, with anticlockwise variation along the day (Fig. 2).

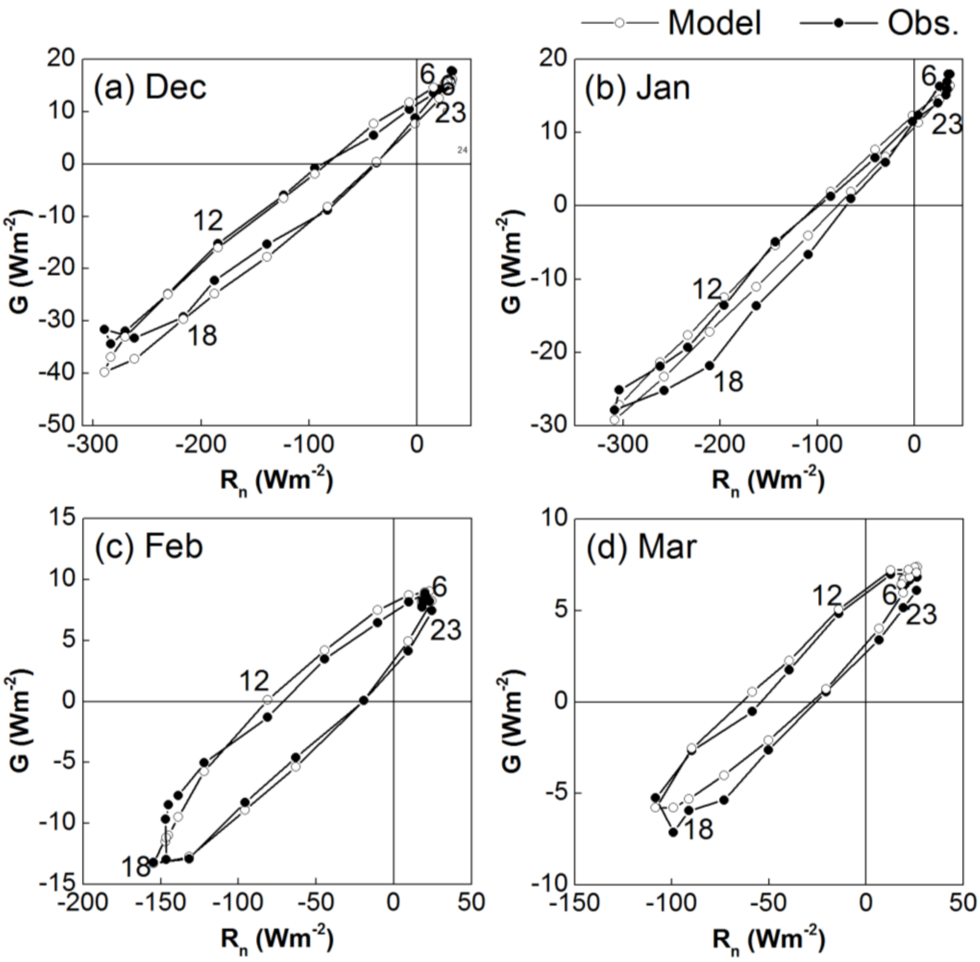

Figure 2. Hysteresis loop relations between soil heat flux (G - observed and modelled) and net all-wave radiation (R_n) for summer period 2013/2014 in EACF: (a) December, (b) January, (c) February, and (d) March. The numbers represent the time (hour).

The comparison with observational and modelled diurnal variation of G, for summer period 2013/2014 in EACF, presented good statistical results, with 99% of correlation between the values for all months in the period (Fig.3).

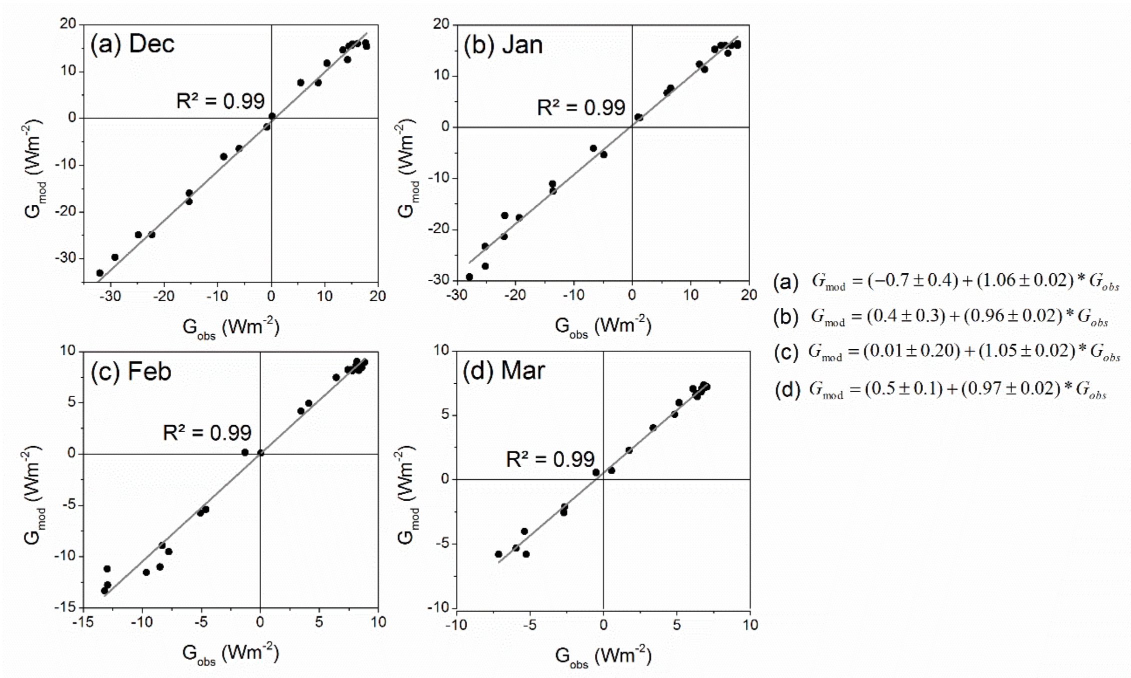

Figure 3. Soil heat flux (G_{obs}) observed vs modelled (G_{mod}) using the OHM method for summer period 2013/2014 in EACF. (a) December, (b) January, (c) February, and (d) March. The gray straight lines represent the equations on the right side.

Conclusions

The OHM model was applied for G estimation, during summer period of 2013/2014, and presented good agreement with the direct measurements of G in EACF. Therefore, this method can be applied when in situ net radiation measurements are available and not soil heat flux measurement in the EACF. In the future, it will be tested the performance of the found coefficients for others summer periods. The idea is finding the best coefficients to estimate the soil heat flux in EACF using only net radiation.

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