Energy balance at the surface in the King George Island-Preliminary results of ETA project

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Abstract

In this work the diurnal evolution of the energy balance at the surface is estimated for St. George Island, based on *in situ* measurements of net radiation, soil heat flux and vertical profiles of wind speed, air temperature and specific humidity carried at the South Tower in the Brazilian Antarctic Station Comandante Ferraz. The turbulent fluxes were estimated by adjusting vertical profiles expressions based on the Monin-Obukhov Similarity Theory. The imbalance term is estimated and discussed.

Keywords: energy balance, sensible heat, latent heat, soil heat flux.

1. Introduction

Quantifying observationally the interaction between surface and atmosphere is one of the most challenging tasks ever. It evolves to estimate exchange of energy, mass and momentum, simultaneously, at different place, facing heterogeneities inherent to surface of Earth at different meteorological scales. Among all ecosystems the one represented by Antarctic is even most changeling yet, given the extreme weather conditions prevailing during most of the time. These difficulties worsen in the case of Brazilian Antarctic Station *Comandante Ferraz* because it is located in the shoreline region of the King George Island (Fig. 1a) that is characterized by highly complex topography (Fig. 1b). Besides, temporal and spatial distribution of precipitation changes continuously the land cover (Fig. 1c).

The main goal of the ETA("*Estudo da Turbulência na Antártica*") project is to estimate the energy fluxes of sensible and latent heat at the surface at the Brazilian Antarctic Station Comandante Ferraz using slow and fast response sensors. In this work the diurnal evolution of the energy balance components are estimated using *in situ* observations of net radiation and soil heat flux. Hourly values of turbulent fluxes were estimating using low response sensors to provide vertical profiles of wind speed, air temperature and specific humidity. Universal nondimensional vertical gradients, provided by the Monin-Obukhov Similarity Theory, were adjusted, by linear fitting technique, to the observed vertical profiles, yielding turbulent fluxes of sensible and latent heat.

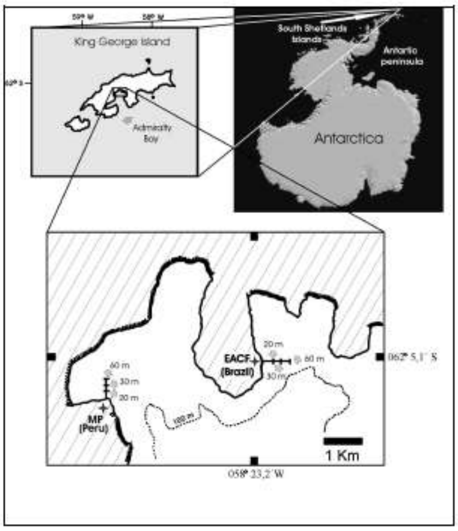
2. Methodology

Energy balance at the surface can be expressed as:

$$Rn = G - H - LE + I$$

Where Rn is the net radiation, G is the soil energy flux, H and LE are the turbulent energy fluxes of sensible and latent heat and I is the imbalance term. The imbalance term takes into account the energy fluxes that are not associated to local sources, systematic errors caused by observations and methodology limitations (Foken, 2008), and phase change of ice at the surface and frozen soil. In this work all energy fluxes are positive when oriented upwards and vice versa.

(a)



(b)

(c)

Figure 1. (a) Geographic position, (b) topography and (c) land use and cover of the South Tower area in the Brazilian Antarctic Station Comandante Ferraz, King George Island, Antarctic.

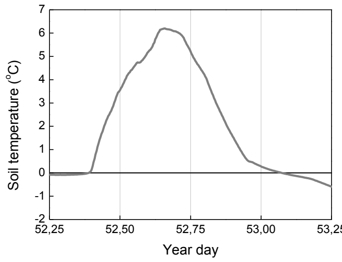
The major reason for the imbalance is that over heterogeneous landscape turbulent exchange processes of larger scales cannot be captured by eddy covariance. Long wave and organized turbulence are not properly described because most of the eddy covariance algorithms does not consider the covariance when the signal is non stationary, so that H+LE is under estimated. Besides, due to wind direction high variability the foot print has to be taken into consideration properly in order to reduce the error in H and LE measurements.

(a)

(b)

(c)

(d)



(e) **(f)**

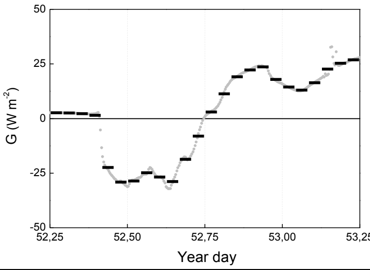
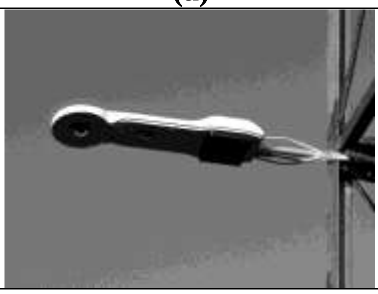


Figure 2. (a) South tower NW face; (b) Soil heat flux position; (c) Soil temperature sensor; (d) Soil temperature at -5.0 cm; (e) Soil heat flux plate; (f) Soil heat flux at -5.0 cm.

Another source of error is caused by phase difference between soil heat flux and surface temperature. Energy balance at the surface respond to the temperature and soil heat flux evolution in time at the surface, the later parameter is measured using heat plates at some depth z so that there is a significant phase and amplitude difference between surface temperature and soil heat flux. Besides, soil heat plates always underestimate the soil heat flux amplitude due to the deflection of heat flux lines of the soil by introducing the plate with different thermal conductivity (Gao *et al*, 2010)

In this work the net radiation is estimated using the net radiometer; soil heat flux is estimate using the soil heat flux plate set up at 5 cm below the surface (Fig. 2 and 3), the sensible and latent heat flux are estimated using vertical profiles of wind speed, air temperature and specific humidity (Fig. 4). Details of these and other sensors used here can be found in Oliveira *et al*. (2012) and Codato *et al.* (2012).

(a) **(b)**



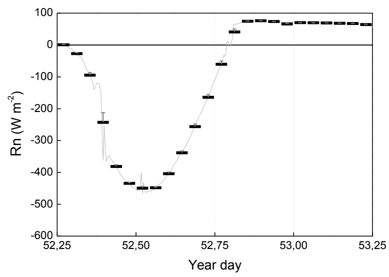


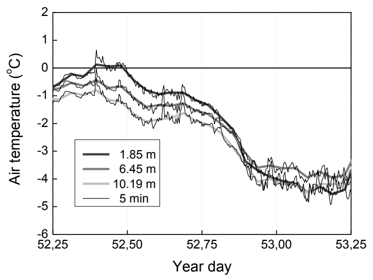
Figure 3. (a) Net radiometer at South Tower; (b) Diurnal evolution of net radiation.

According to Monin-Obukhov Similarity Theory, the mean vertical profiles of horizontal wind speed, potential temperature and specific humidity can be expressed in terms of nondimensional universal relations (Wyngaard, 2010). These functions, depend on the stability of the surface layer and can be used to estimate the characteristic scales of velocity (u_*), temperature (θ_*) and specific humidity (q_*).

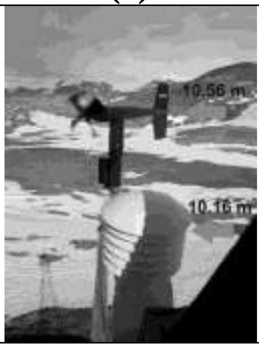
(a)

(b)

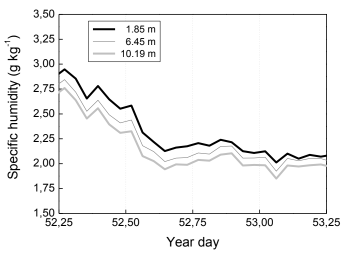
(c)



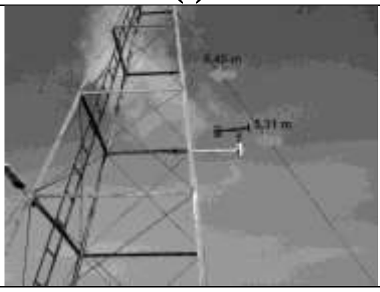
(d)



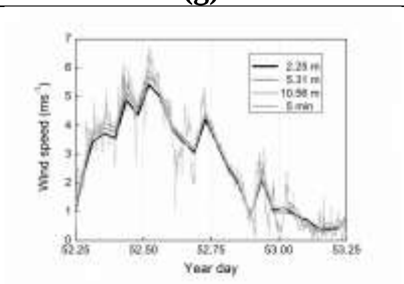
(e)



(f)



(g)



(h)

(i)

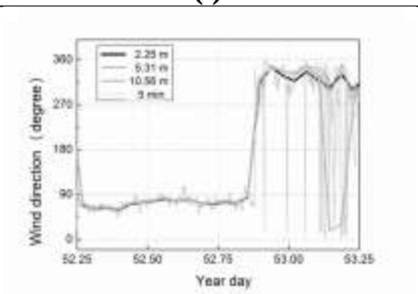


Figure 4. (a) Sensor setup in South Tower; (b) South Tower; (c) Air temperature at 3 levels; (d) Upper level sensors; (e) Specific humidity at 3 levels; (f) Middle level sensors; (g) Wind speed; (h) Lower level sensors; (i) Wind direction.

The turbulent fluxes of sensible and latent heat are evaluated by the following expressions:

$$H = - \rho c_p u_* \theta_* \qquad LE = - \rho L u_* q_*$$

Where ρ is de air density, c_P is the specific heat at constant pressure and L is the latent heat of vaporization.

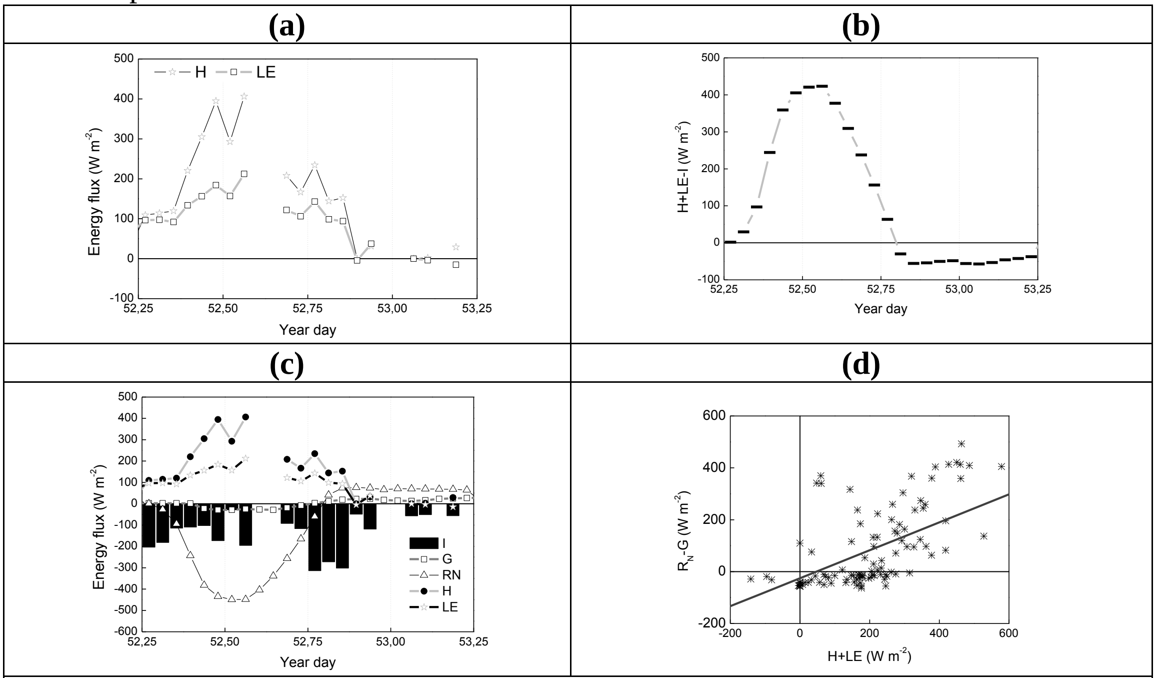


Figure 5. (a) Sensible and latent heat (b) Energy flux available (c) Energy balance; (d) Dispersion diagram (year day 50-55).

3. Discussion and conclusion

The diurnal evolution of the energy balance components at the surface indicates that in this particular period (year day 52-53) there was a large input of energy, heating considerably the surface and the surface layer (Fig. 5). There is a substantial imbalance that may be related to the methodology used to estimate the turbulent fluxes (Indirect method), lack of representativeness of the soil heat flux and advection of heat. The next step is to compare the indirect method with the eddy correlation method. This will be possible if the sonic anemometer and infrared gas analyzer are setup in the South Tower as proposed in the ETA project (Oliveira, et al, 2012).

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