Multi-scale analysis of energy partitioning over a young beech forest using continuous wavelet transform

Jonathan Bitton[1*], Catherine Charles[1] and Bernard Heinesch[1]

[1]University of Liege—Gembloux Agro-Bio Tech, TERRA Teaching and Research Centre, Biosystems Dynamics and Exchanges (BIODYNE), Avenue de la Faculté, 8, B-5030 Gembloux, Belgium

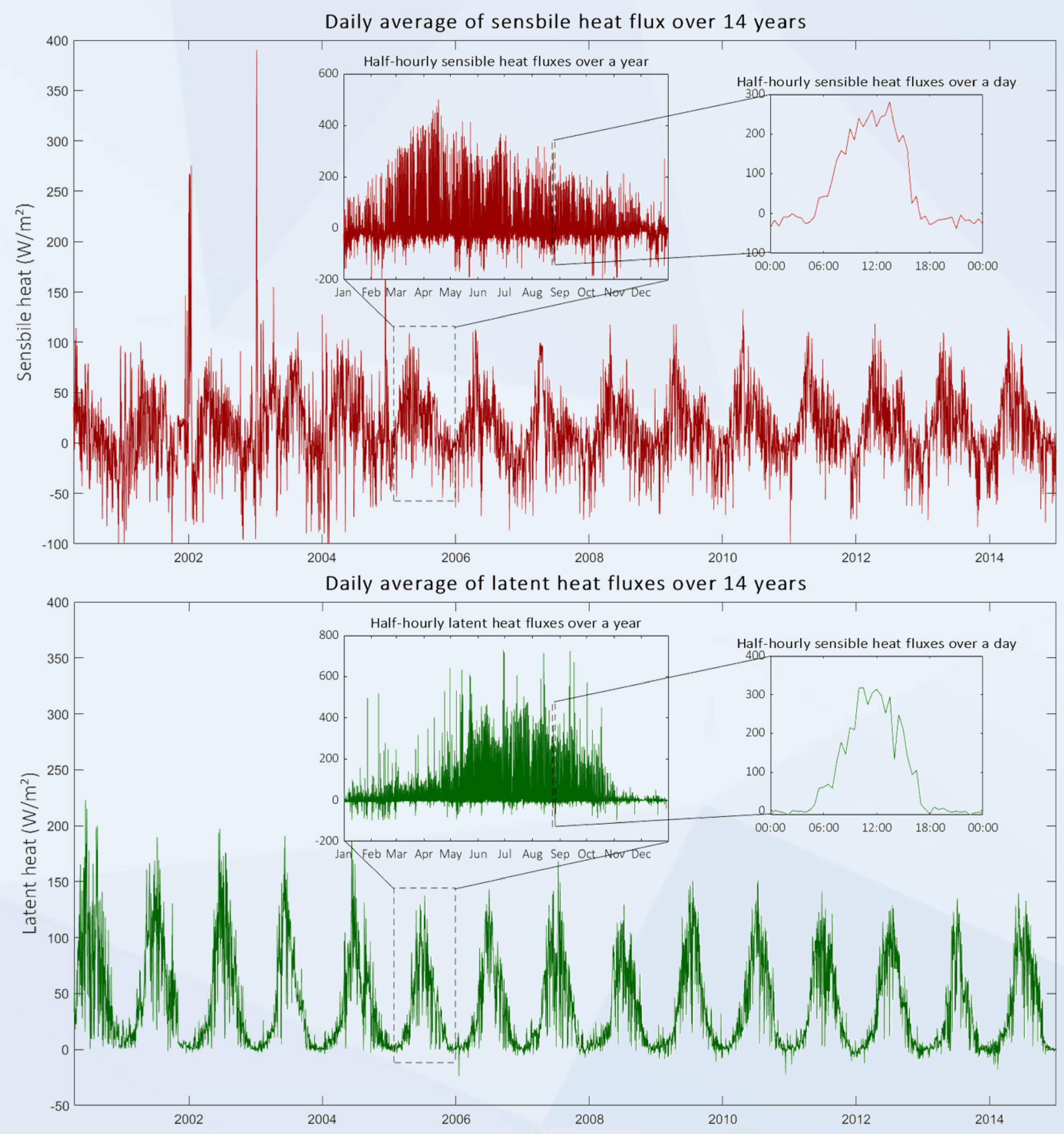
* Corresponding author: jbitton@student.uliege.be

INTRODUCTION

Energy exchanges of an ecosystem are directly linked to the surrounding atmosphere's physical status. In the light of the actual global warming phenomenon, understanding these energy fluxes evolution is highly valuable due to their forecasting potential on the atmosphere's state. This study focuses on latent (LE) and sensible (H) heat, also known as the available energy of an ecosystem. The objective is to derive processes governing these turbulent heat fluxes on an annual and multi-annual scale. In this context, wavelet analysis has already established itself as a powerful time-frequency investigation tool, allowing to expand the scope of actual eco-physiological studies.

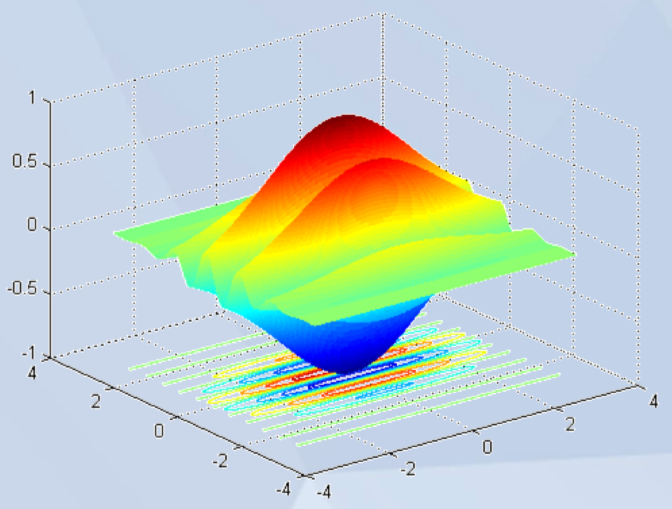
SIGNAL

Data was collected using the Eddy Covariance micro-meteorology measurement method. Both studied turbulent fluxes present a characteristic annual pattern. This pattern is itself composed of a recurring daily evolution, which is Gaussian shaped.



METHODOLOGY

The continuous wavelet transform allows to decompose the analyzed signal in the time-frequency space, conferring high capability for investigating non-stationary phenomena. This study uses the Morlet wavelet as analyzing function. Its complex nature allows to extract both amplitude and phase information. The significance contours are traced assuming a red noise background, validated by bootstrapping methods.



On an annual scale, both signals are out of phase, with a time lag of 47.41 ± 3.37 days. Positive values indicate H leading LE. This result is supposed to reflect the divergence of the processes driving both fluxes: LE mostly depends on the evapotranspiration ability of the ecosystem, and thus, on the state of the vegetation while H is driven by the temperature difference between the ecosystem and surrounding atmosphere. Keeping in memory that incoming energy is distributed between these two fluxes, H reaches its peak value right before the growing season, that is to say, before LE starts to increase and eventually takes over.

On a daily scale, H and LE seem to evolve in phase, with a shift of 0.40 ± 0.38 hours. However, by dissociating the growing season from the rest of the year, time lags of respectively 0.63 ± 0.21 hours (growing season) and 0.08 ± 0.25 hours (rest of the year) are found. This difference can be explained by the influence of the vapor pressure deficit: LE reaches its peak value later than H during the growing season due to its response to the vapor pressure deficit, whose daily evolution is not centered on the zenith.

On intermediate scales, many repeating behaviors take place between monthly and semi-yearly periods. Following previous researches, they may be linked to the seasonal depletion of water resources. This phenomenon directly influences LE fluxes by limiting the availability of water for evapotranspiration processes and thus inducing stomatal closure.

The studied site has been thinned three times over the studied period, in March 2002, December 2005 and December 2009. No significant component seems to appear during those three dates. This result, in compliance with previous studies conducted over Hesse site, underlines the fact that thinning events do not influence H and LE fluxes in a distinguishable way compared to their natural variability.

RESULTS AND DISCUSSION

Sensible and latent heat scalograms highlight an annual periodic component. A daily periodic evolution is also detected, mostly during each year's growing season. These behaviors are directly related to the amount of solar radiation perceived by the ecosystem.

At intermediate scales, highly non-stationary periodic components can be observed. They could be related to weather fronts or extreme climatic events, both of which have previously been shown to have an influence at these scales.

Semi-annual and semi-diurnal significant components seem to be an artificial behavior related to the Gaussian shape of the signals.