Multi-scale analysis of the evolution of surface turbulent heat fluxes using continuous wavelet transform

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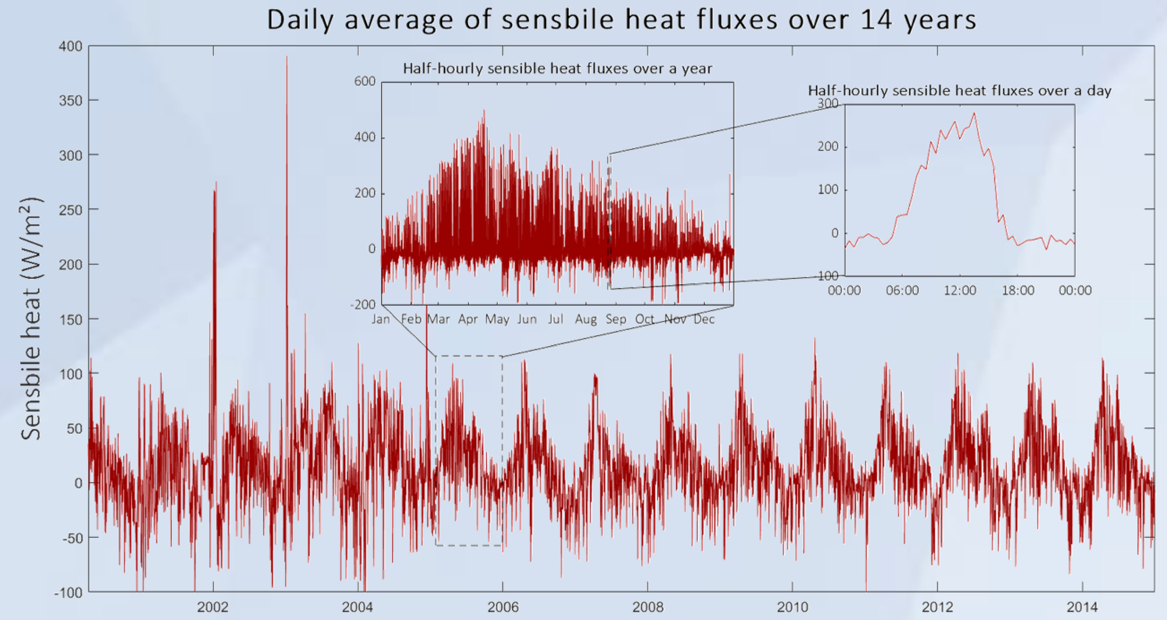
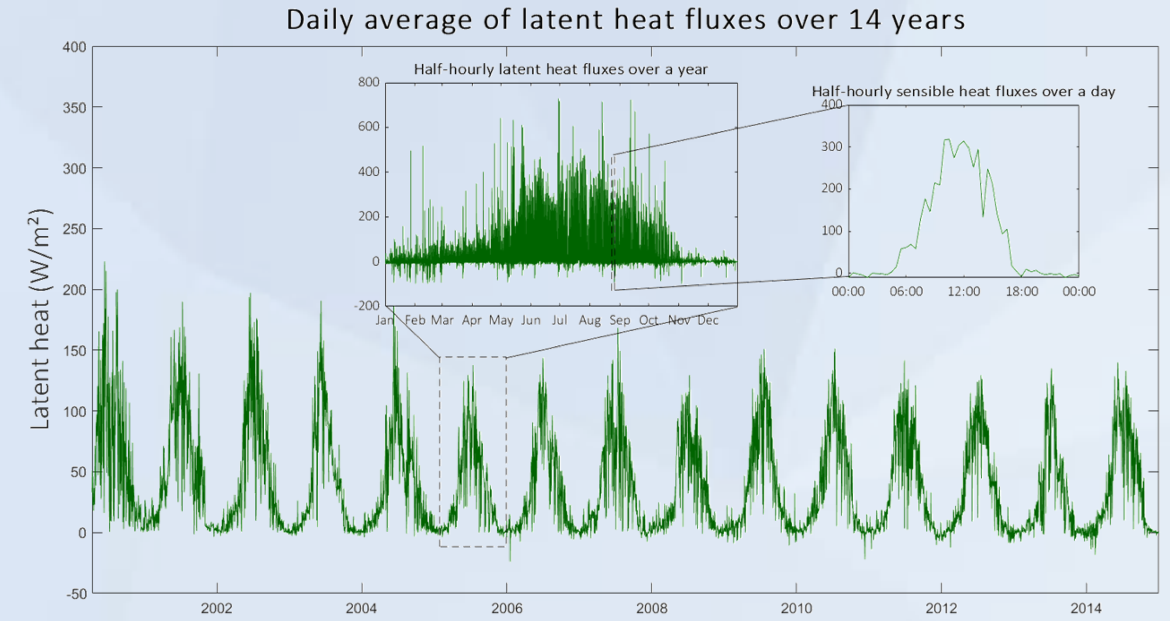
INTRODUCTION

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.

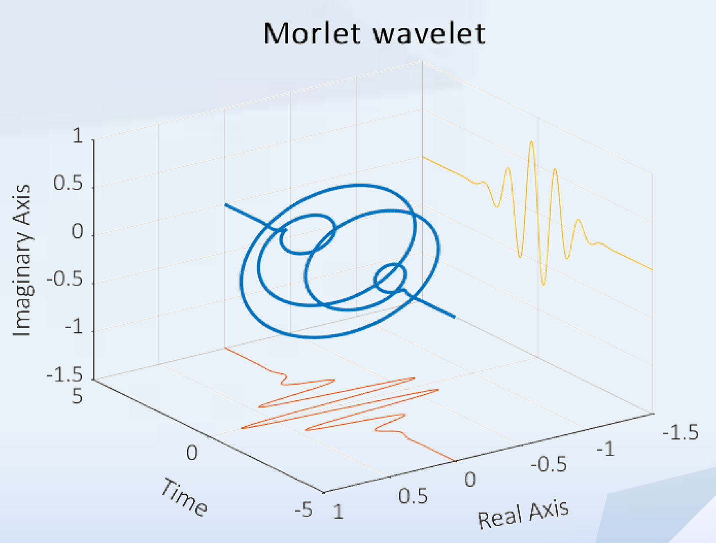
METHODOLOGY

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



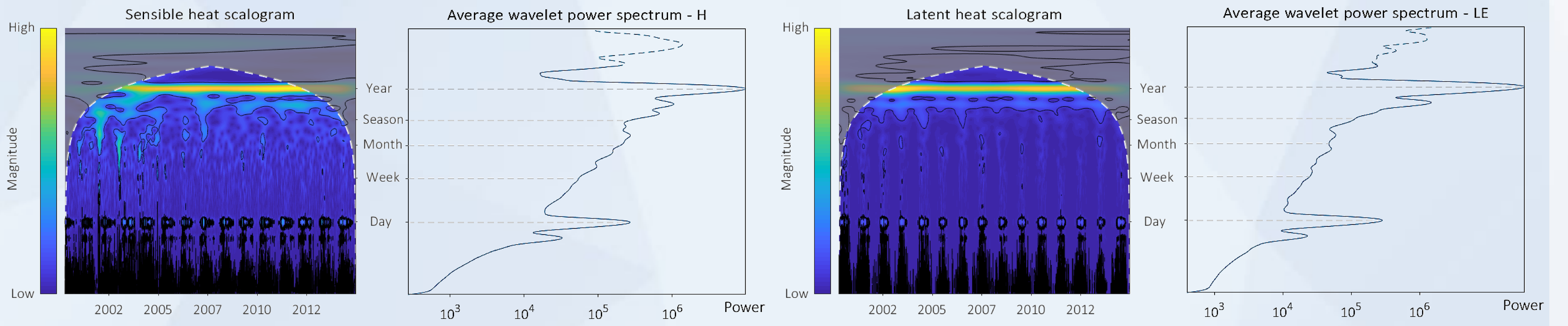


The continuous wavelet transform is applied using the Morlet wavelet. Its complex nature allows a study in amplitude and phase. To compute the wavelet coefficients, an algorithm based on a Fourier transform is adopted as a result of the application of the cross-correlation theorem. In the case of this study, the cone of influence is defined as the region where the wavelet power induced by a discontinuity at the edge of the signal decays to 2% of its peak value at each scale. The significance contours are traced assuming a red noise background, validated by bootstrapping methods.

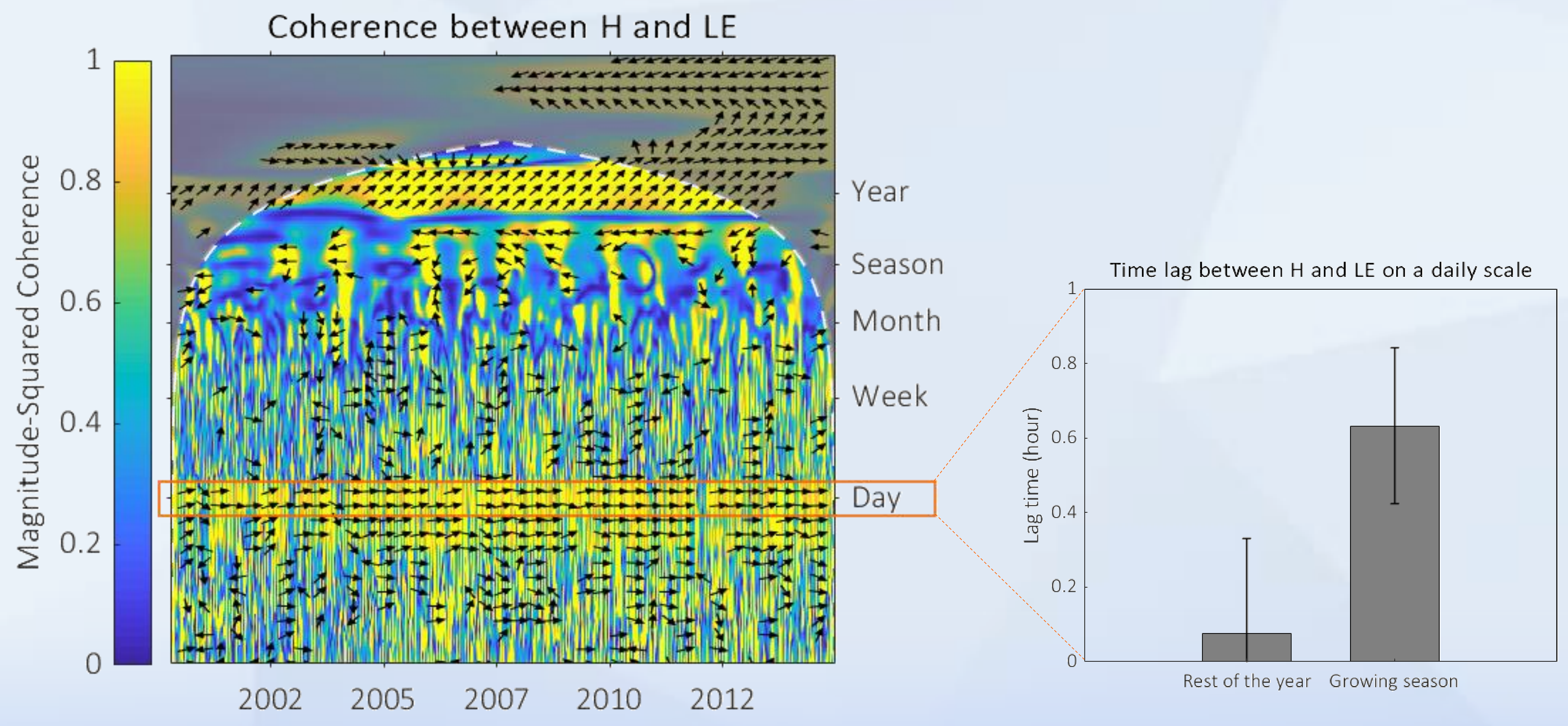


RESULTS AND DISCUSSION

Latent and sensible 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. Semi-annual and semi-diurnal significant components may be related to the Gaussian shape of the signals.



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.