Signal Processing Techniques for Analyzing Long-term Flux Measurements

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Motivation

Variability in carbon and water fluxes varies at scales ranging from fractions of seconds to decades.

Long-term variation in these fluxes is also compounded by non-stationary shifts in ecophysiological and ecological attributes.

Sampling fluxes is often “infected” with large gaps (~30 % of times).

Problem:

How can we assess the “critical” scales of flux variability and their relationship to environmental variables?

Approach

- Gap Filling Strategies – Falge et al. (2001)

→ The choice of the strategy is subjective

→ Some strategies "inject" artificial correlations between environmental drivers and fluxes.

There is a need for synergistic approaches that complement and independently assess gap-filling strategies.

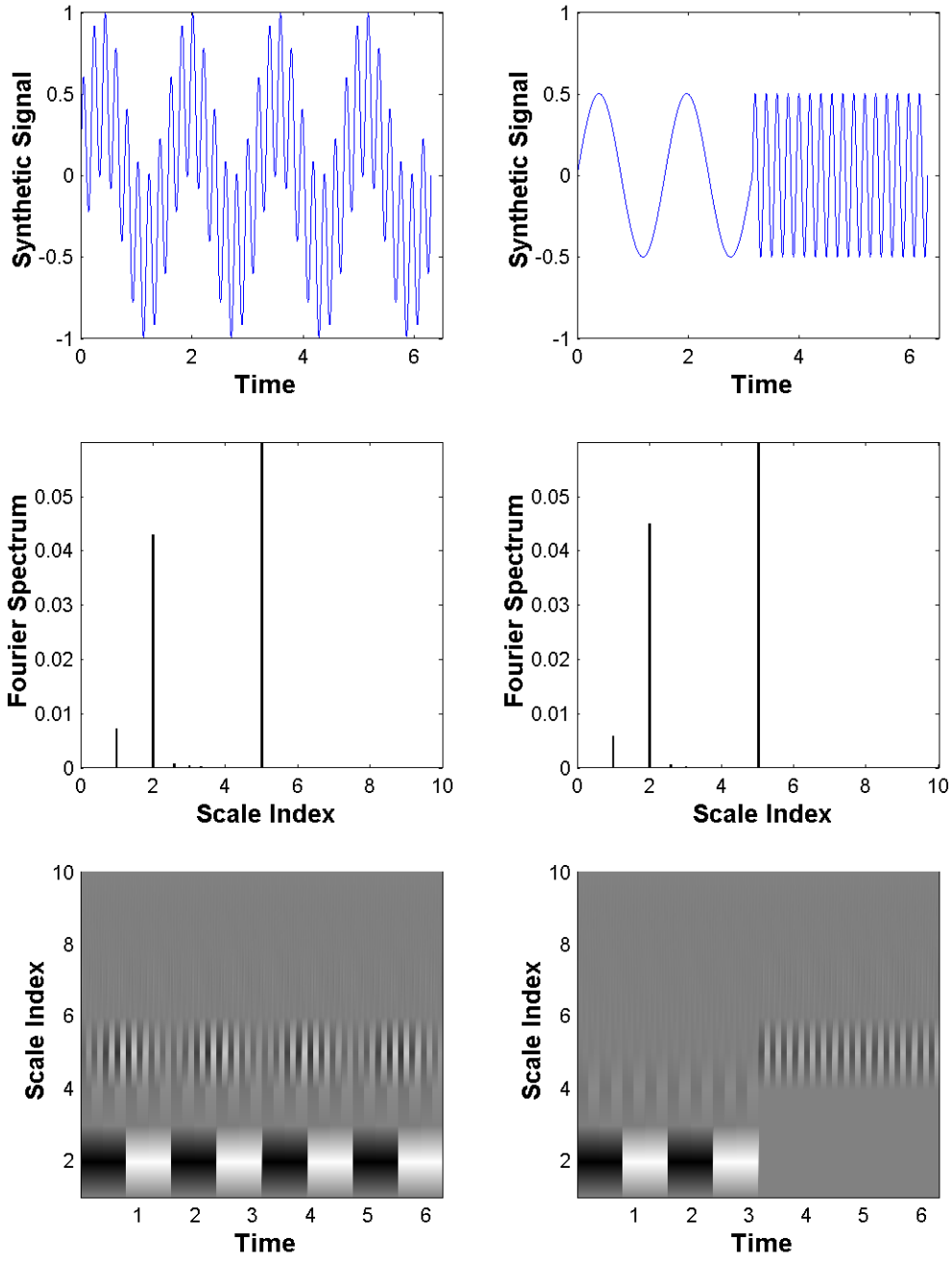
Approach:

We propose multi-resolution analysis to "complement" and "diagnose" gap-filling strategies – not substitute them.

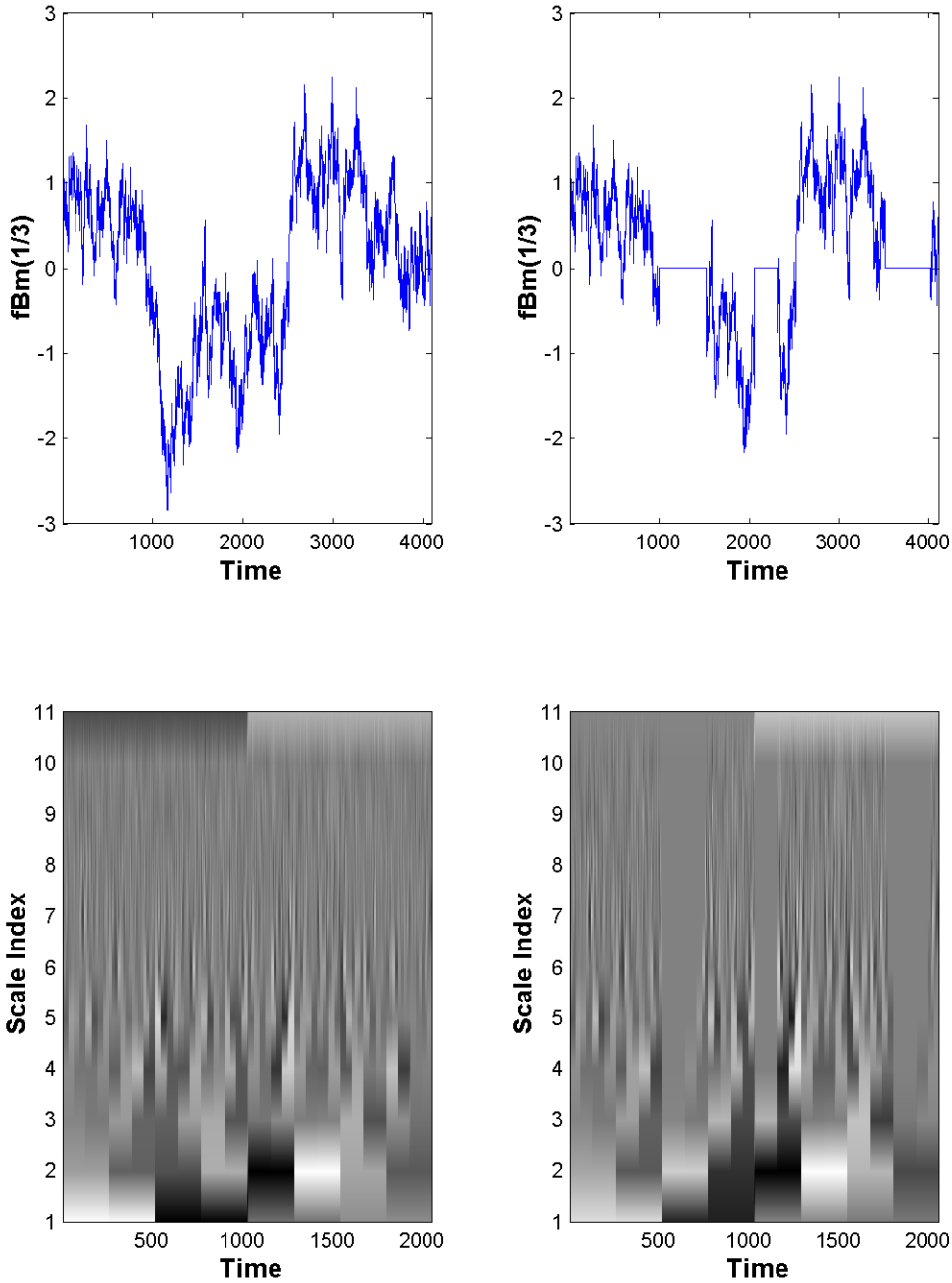
Multi-resolution methods offer independent assessment of the variability in the "flux data" in time-scale "bands" without resorting to subjective gap-filling.

Multi-resolution methods use orthonormal wavelets which can unfold a given time series into time and frequency domains.

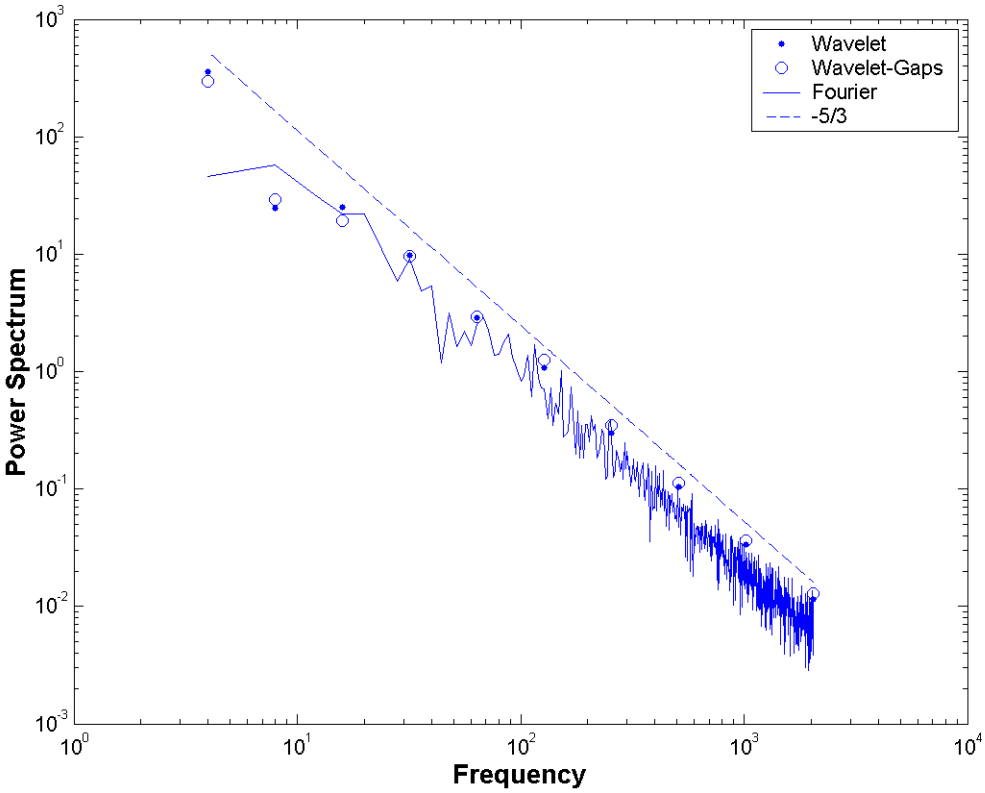
SYNTHETIC EXAMPLE



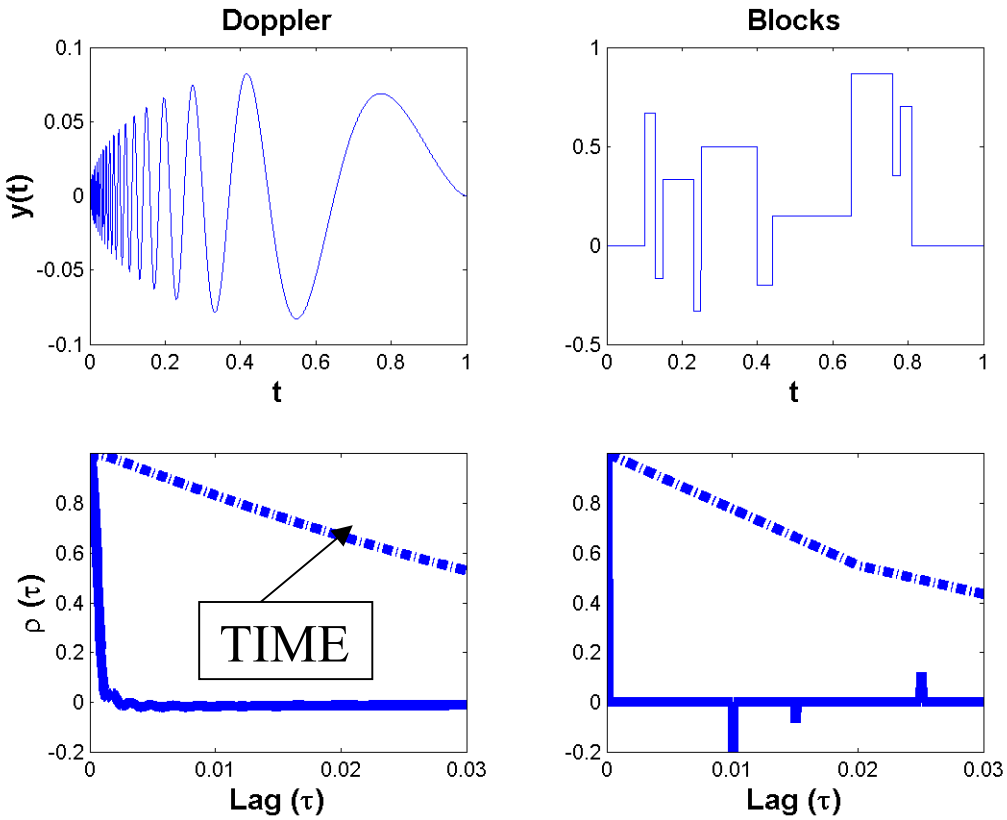
EFFECT OF GAPS:



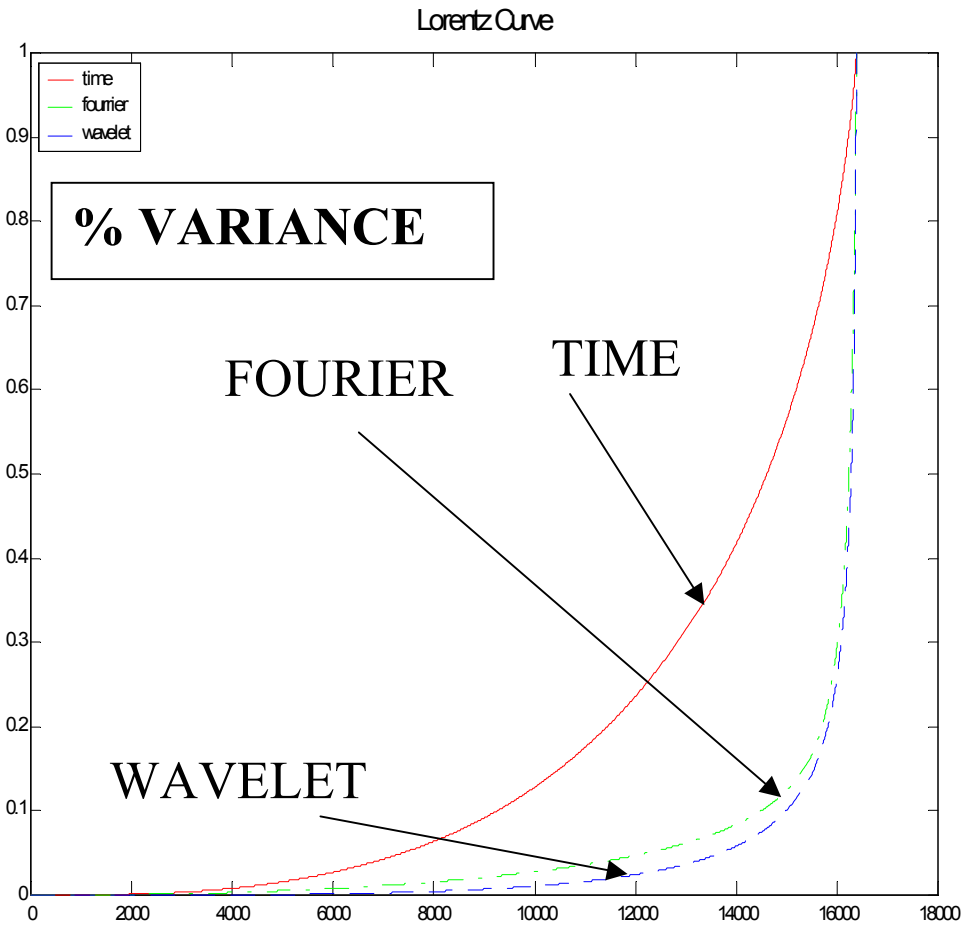
WAVELET SPECTRAL RECOVERY



WHITENING PROPERTY



DISBALANCING PROPERTY



COEFFICIENTS RETAINED

LIMITATIONS

Qui, Paw U, and Shaw (1995) - JGR:

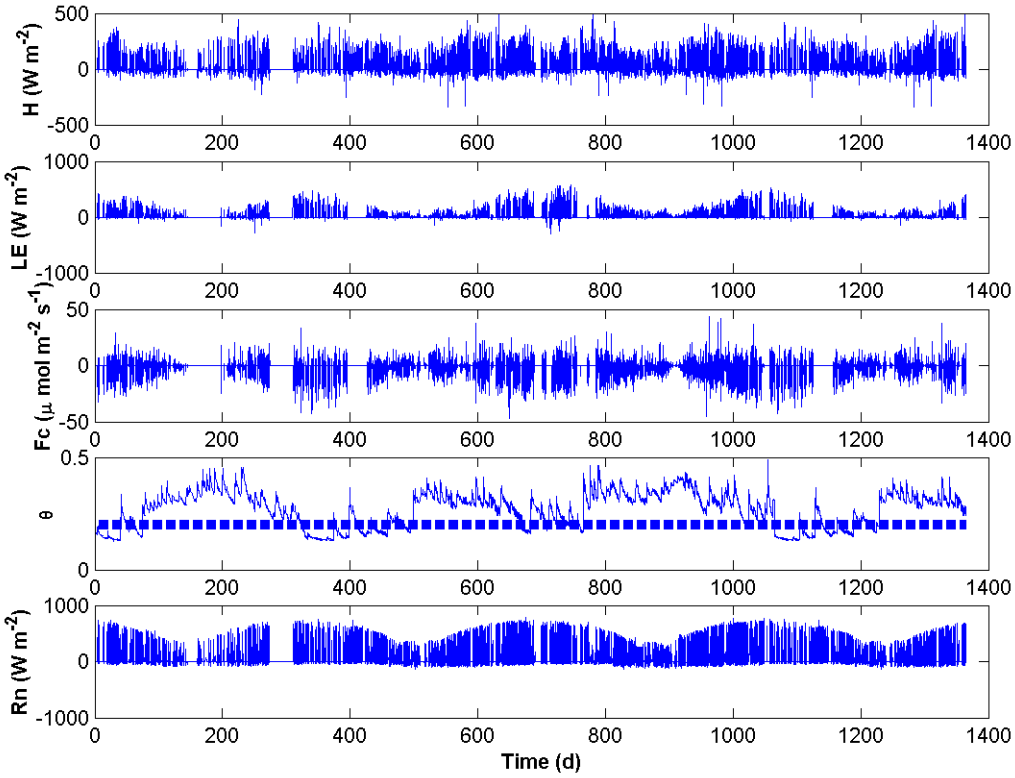
- Limited scale resolution means that variability (or energy) at a precise frequency cannot be resolve.

- Nonlocality of the wavelet in the frequency domain ➔ “Energy leakage”.

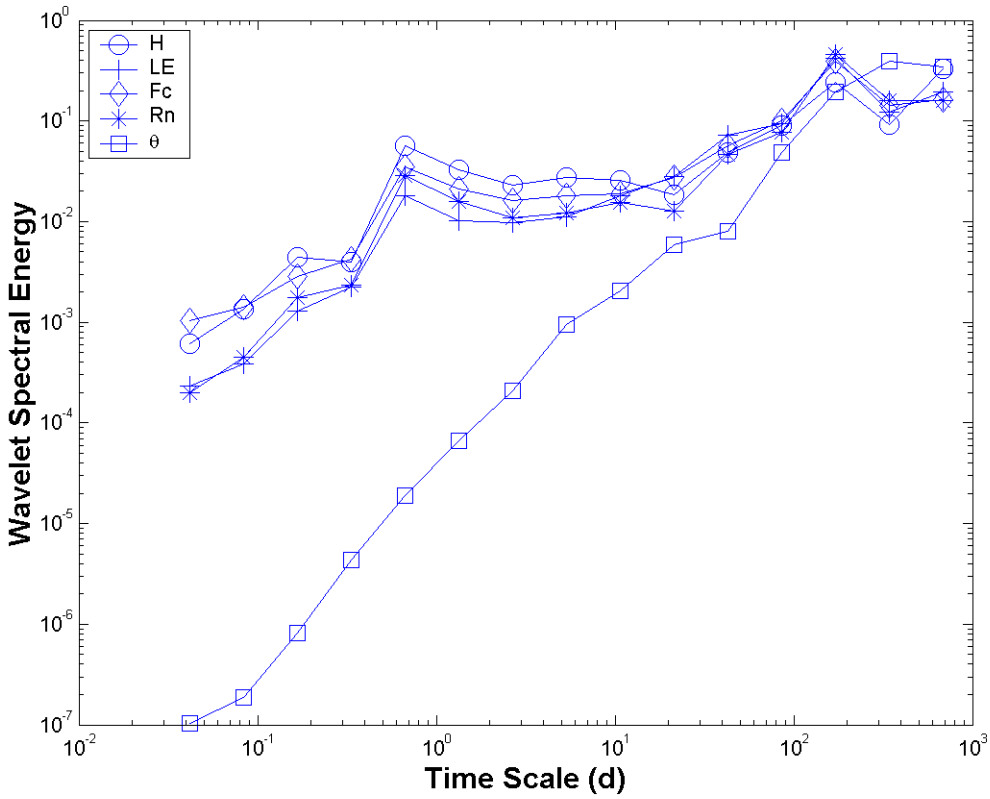
APPLICATIONS

CASE STUDY:

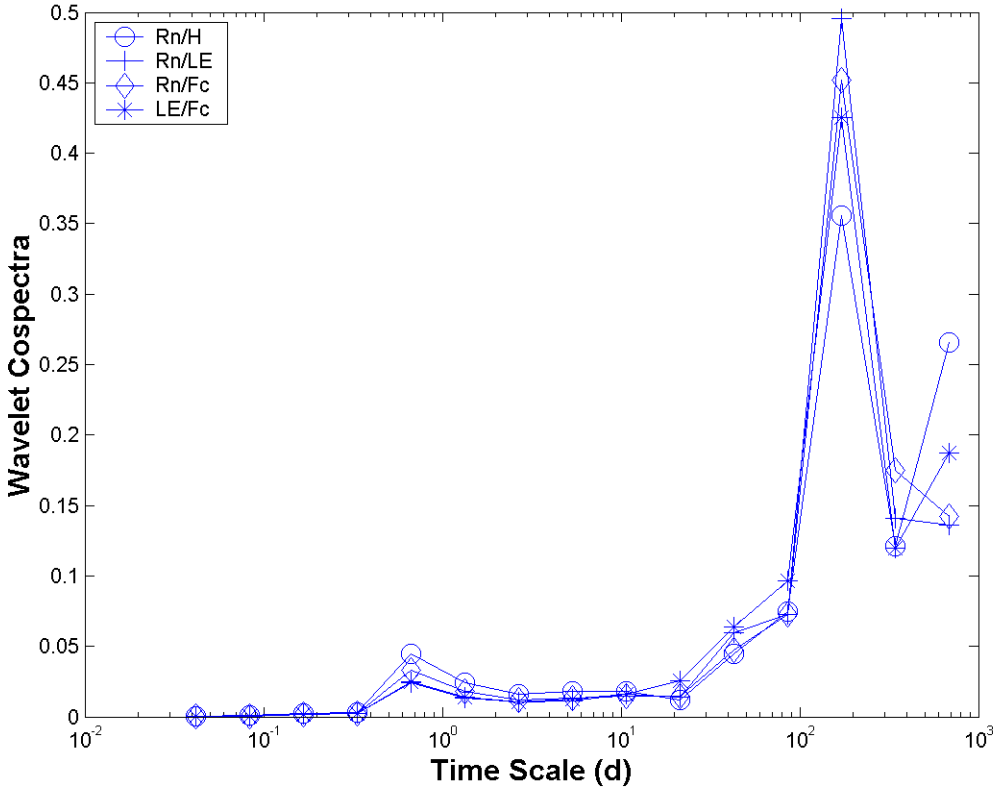
DUKE AMERIFLUX PINE FOREST



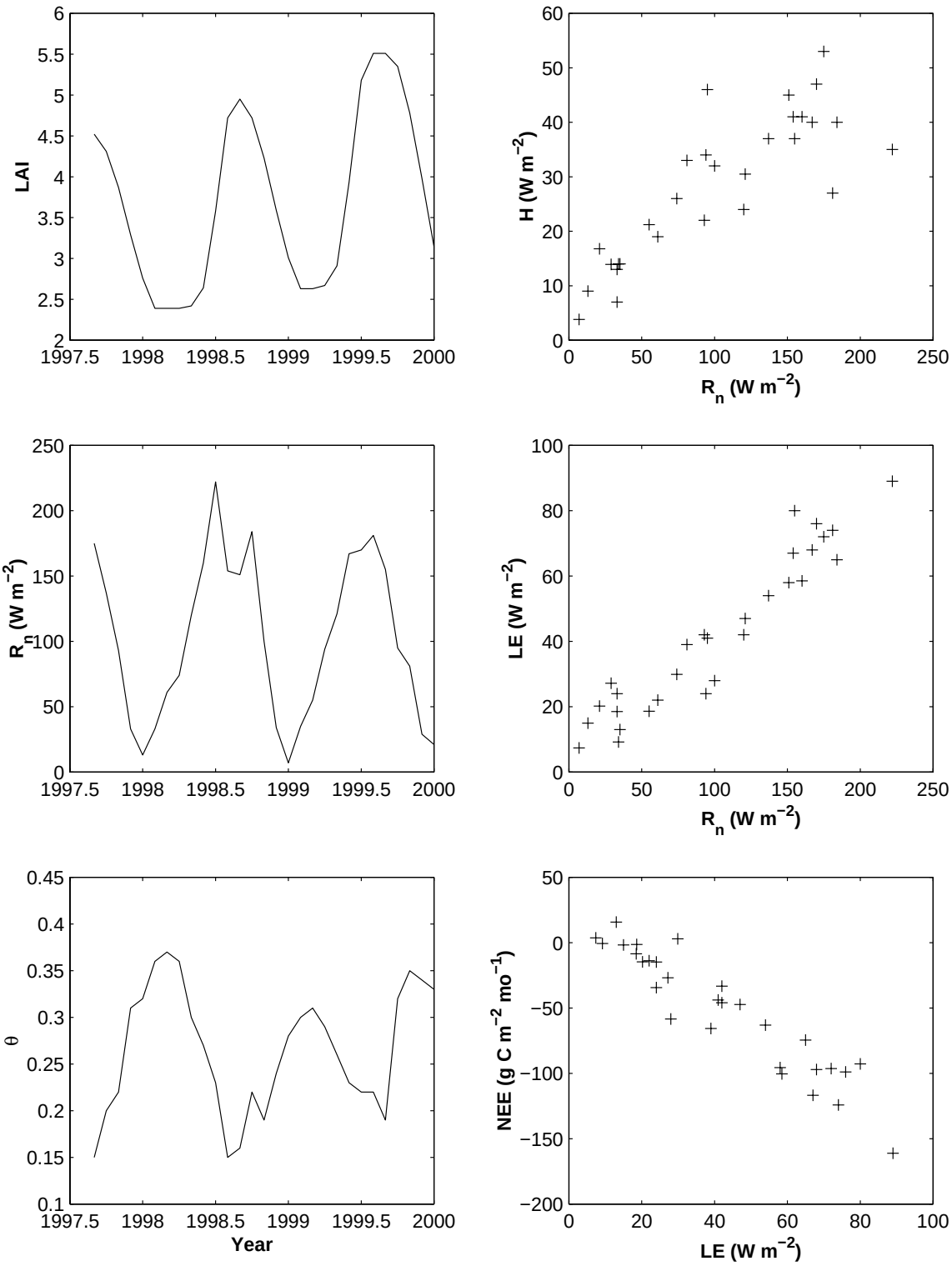
Sample flux time series collected above the Duke Forest AmeriFlux site along with soil moisture and net energy.



FOR SPECTRAL COMPARISONS – ALL VARIABLES ARE NORMALIZED.



CO-SPECTRA: ALL VARIABLES ARE NORMALIZED SO THAT AREA IS UNITY.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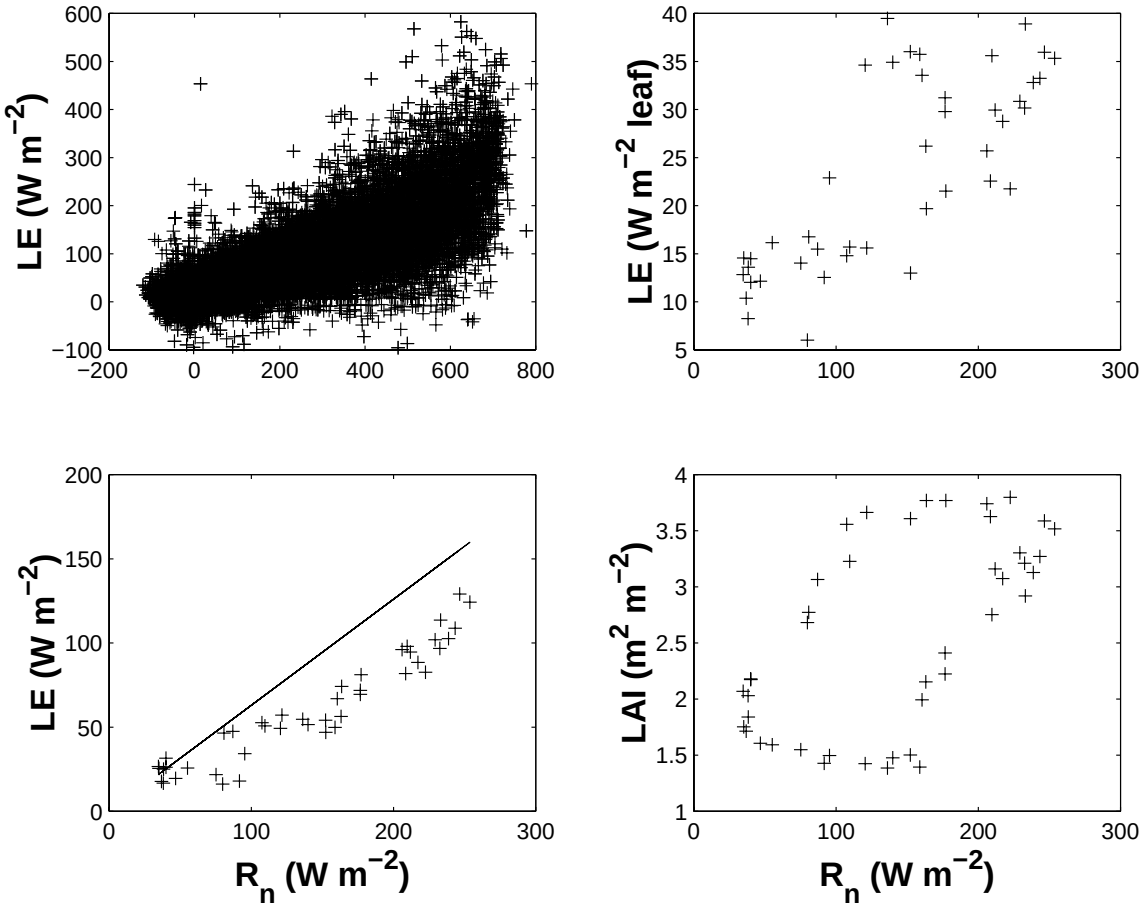
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LE (W m−2)
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Rn (W m−2)
Rn (W m−2)

Conclusions:

- Orthonormal wavelet transformation provides a robust framework for analyzing the spectral and cospectral properties of long-term flux records that exhibit:

1) frequency shifts in time, and
2) multiple gaps or missing data.

- The wavelet spectra of the three land surface fluxes (carbon, water, and heat) demonstrated that the largest variability occurs at seasonal time scales.

Broader Implications:

Current use of remotely sensed data to infer land-surface fluxes benefits from this analysis in two ways:

- It identifies the time scales at which the remotely sensed observations are most correlated with the fluxes and hence the time scales at which remotely sensed observations must be resolved.

- It identifies the level of predictability that simple models can offer given the observed degree of spectral correlation.

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