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Unbiased and biased estimators of the wavelet variance, with application to marine atmospheric boundary layer turbulence

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The wavelet variance is a scale-based decomposition of the variance of a random process that is particularly well-suited for analyzing intrinsically stationary processes. This decomposition has proven to be useful for studying various geophysical time series, including subtidal sea level variations, vertical shear in the ocean and variations in soil composition along a transect. Previous work has established the large sample properties of an unbiased estimator of the wavelet variance formed using the nonboundary wavelet coefficients from the maximal overlap discrete wavelet transform (MODWT). The present work considers three alternative estimators. The first, a new unbiased estimator, is appropriate for asymmetric wavelet filters such as the Daubechies filters of width four and higher and is based upon running the filter through the time series in both a forward and a backward direction. The second, a biased estimator, uses all available MODWT wavelet coefficients formed in conjunction with reflection boundary conditions. The third is a 'weakly biased' estimator that uses a selection of boundary coefficients dictated by the equivalent width of the wavelet filter. While the three alternative estimators have the same asymptotic distribution as the original unbiased estimator, they can have substantially better statistical properties in small sample sizes. As an example, the original and alternative estimators are applied to estimate the wavelet variance of marine atmospheric boundary layer turbulence.