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Historical Open-High-Low-Close Volatility: Yang Zhang

created by **Thijs van den Berg**

$$\sigma^2 = \sigma_o^2 + k\sigma_c^2 + (1-k)\sigma_{rs}^2$$

$$\sigma_o^2 = \frac{Z}{n-1}\sum\left(\ln\frac{O_i}{C_{i-1}} - \mu_o\right)^2$$
$$\mu_o = \frac{1}{n}\sum\ln\frac{O_i}{C_{i-1}}$$
$$\sigma_c^2 = \frac{Z}{n-1}\sum\left(\ln\frac{C_i}{O_i} - \mu_c\right)^2$$
$$\mu_c = \frac{1}{n}\sum\ln\frac{C_i}{O_i}$$
$$\sigma_{rs}^2 = \frac{Z}{n}\sum\left(\ln\frac{H_i}{C_i}\ln\frac{H_i}{O_i} + \ln\frac{L_i}{C_i}\ln\frac{L_i}{O_i}\right)$$
$$k = \frac{0.34}{1+\frac{n+1}{n-1}}$$

Yang and Zhang were the first to derive an historical volatility estimator that has a minimum estimation error, is independent of the drift, and independent of opening gaps. This estimator is maximally 14 times more efficient than the close-to-close estimator.
It can be interpreted as a weighted average of the Rogers and Satchell estimator, the close-open volatility and the open-close volatility.
The performance degrades to the classic close-to-close estimator when the price process is heavily dominated by opening jumps.

Symbol list:

σ	Volatility
Z	Number of closing prices in a year
n	Number of historical prices used for the volatility estimate
O_i	The opening price
H_i	The high
L_i	The low
C_i	The close