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STL: A Seasonal-Trend Decomposition Procedure Based on Loess

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Abstract: STL is a filtering procedure for decomposing a time series into trend, seasonal, and remainder components. STL has a simple design that consists of a sequence of applications of the loess smoother; the simplicity allows analysis of the properties of the procedure and allows fast computation, even for very long time series and large amounts of trend and seasonal smoothing. Other features of STL are specification of amounts of seasonal and trend smoothing that range, in a nearly continuous way, from a very small amount of smoothing to a very large amount; robust estimates of the trend and seasonal components that are not distorted by aberrant behavior in the data; specification of the period of the seasonal component to any integer multiple of the time sampling interval greater than one; and the ability to decompose time series with missing values.

Key words: Seasonal adjustment; time series; loess.

1. Introduction

STL is a filtering procedure for decomposing a seasonal time series into three components: trend, seasonal, and remainder. Figure 1 shows an example. The data, graphed in the first (top) panel, are daily average measurements of atmospheric carbon dioxide (CO_2) made at the Mauna Loa Observatory in Hawaii (Komhyr and Harris 1977). The second panel graphs a trend component: the low frequency variation in the data together with nonstationary, long-term changes in level. The third panel graphs a seasonal component: variation in the data at or near the seasonal frequency, which in this case is one cycle per year. The remainder component, shown in the fourth panel, is the remaining variation in the data beyond that in the seasonal and trend components. That is, suppose the data, the trend component, the seasonal component, and the remainder component are denoted by Y_v, T_v, S_v, and R_v, respectively, for $v = 1$ to N. Then

$$Y_v = T_v + S_v + R_v.$$

The measurements in Figure 1 were made by the U.S. National Oceanic and Atmospheric Administration, or NOAA, as part of a worldwide government program to monitor CO_2 concentrations. The measurements

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