World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:15, No:02, 2021

An Adaptive Decomposition for the Variability Analysis of Observation Time Series in Geophysics

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Abstract : Most observation data sequences in geophysics can be interpreted as resulting from the interaction of several physical processes at several time and space scales. As a consequence, measurements time series in geophysics have often characteristics of non-linearity and non-stationarity and thereby exhibit strong fluctuations at all time-scales and require a time-frequency representation to analyze their variability. Empirical Mode Decomposition (EMD) is a relatively new technic as part of a more general signal processing method called the Hilbert-Huang transform. This analysis method turns out to be particularly suitable for non-linear and non-stationary signals and consists in decomposing a signal in an auto adaptive way into a sum of oscillating components named IMFs (Intrinsic Mode Functions), and thereby acts as a bank of bandpass filters. The advantages of the EMD technic are to be entirely data driven and to provide the principal variability modes of the dynamics represented by the original time series. However, the main limiting factor is the frequency resolution that may give rise to the mode mixing phenomenon where the spectral contents of some IMFs overlap each other. To overcome this problem, J. Gilles proposed an alternative entitled “Empirical Wavelet Transform” (EWT) which consists in building from the segmentation of the original signal Fourier spectrum, a bank of filters. The method used is based on the idea utilized in the construction of both Littlewood-Paley and Meyer’s wavelets. The heart of the method lies in the segmentation of the Fourier spectrum based on the local maxima detection in order to obtain a set of non-overlapping segments. Because linked to the Fourier spectrum, the frequency resolution provided by EWT is higher than that provided by EMD and therefore allows to overcome the mode-mixing problem. On the other hand, if the EWT technique is able to detect the frequencies involved in the original time series fluctuations, EWT does not allow to associate the detected frequencies to a specific mode of variability as in the EMD technic. Because EMD is closer to the observation of physical phenomena than EWT, we propose here a new technic called EAWD (Empirical Adaptive Wavelet Decomposition) based on the coupling of the EMD and EWT technics by using the IMFs density spectral content to optimize the segmentation of the Fourier spectrum required by EWT. In this study, EMD and EWT technics are described, then EAWD technic is presented. Comparison of results obtained respectively by EMD, EWT and EAWD technics on time series of ozone total columns recorded at Reunion island over [1978-2019] period is discussed. This study was carried out as part of the SOLSTYCE project dedicated to the characterization and modeling of the underlying dynamics of time series issued from complex systems in atmospheric sciences

Keywords : adaptive filtering, empirical mode decomposition, empirical wavelet transform, filter banks, mode-mixing, non-linear and non-stationary time series, wavelet
Conference Title : ICCWECV 2021 : International Conference on Climatology, Weather Events and Climate Variability
Conference Location : Kuala Lumpur, Malaysia
Conference Dates : February 11-12, 2021