Application of Hilbert-Huang Transform in Methane Concentration

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SUMMARY

Methane is the second most important anthropogenic greenhouse gas, and observation data from Waliguan Baseline Observatory since 1991 showed that methane concentrations have increased. Most previous studies focused on single source which may cause changes in methane concentration, while the growth rate of the methane concentration is relatively less, and there is no report about the intrinsic law of methane growth from the macro analysis. In this paper, we adopt a relatively new spectral analysis method named Hilbert-Huang transform to process Waliguan 1991.5 ~ 2008.12 methane observations, which start from the data itself, and got five intrinsic cycles are as follows: 4-month, 7-month, about 1-year, about 2-year, about 5-year and about 11-year. This rule will be important for further study on characteristics of sources and sinks of methane.

Keywords: Methane, Hilbert-Huang Transform, Mt. Waliguan, Time-frequency-amplitude

INTRODUCTION

Methane is the second important anthropogenic greenhouse gas, controlling methane concentration has a huge efforts on the mitigation of climate change[1][2][3]. There are lots of studies on the methane concentration variation, such as model research on methane emissions[4][5], and down-top method related such as field measurement study[6][7], and economic analysis study such as reference[8] and[9], and the process-based model such as reference [10] and so on. These researches mainly focused on single source which may cause the methane concentration change. Other researches focused on the ice core records to trace history methane concentration changes, such as references [11][12][13].

Research on the methane growth rate is rather less. Dlugokencky E. put forward the concept of methane instantaneous growth rate in 1998. He adopted the Fast Fourier Transform (FFT) as the measurement data analysis tool and acquired the growth rate trend. James S. Wang et al. used a 3-D chemical transport mode accounting for interannually varying emissions, transport, and sinks to analyze trends in CH_4 from 1988 to 1997. The model captured the general decrease in the CH_4 growth rate observed from 1988 to 1997 and the anomalously low growth rates during 1992-1993. They thought that the slowdown in the growth rate was attributed to a combination of slower growth of sources and increases in OH. So far there is no good explanation about the methane growth rate. To explore the intrinsic oscillation of the methane concentration may help us to understand the variation characteristic and the affecting factors of methane, and may predict well the future CH_4 change.

Methane concentration measurement data is non-stationary, non-linear, so it is necessary to choose an adaptive method which can be based on the local characteristic time scale of the data. Fourier method is the most common data analytic technology used for periodic signal, and the signals must be linear and stationary. But a new data analytical tool, Hilbert-Huang Transform was put forward by N. E. Huang in 1998, it can deal with nonlinear and non-stationary signal. Although the strict logic mathematic theory is still studying, this method has been applied in a wide area, such as to discover synoptic and climatic features: For sea level data, the transforms capture the oceanic tides as well as variations in precipitation patterns and proved that this technique can detect signals on synoptic to inter-annual time scales[14]. Reference [15] analyzed a month of boundary layer wind profiler data with HHT. Reference [16][17]

use HHT to reexamine the reference frame for anomalies by reexamining the annual cycle in climate science. As mentioned above, HHT has been adopted widely and its use in exploring the full physical meanings of complicated data showed a huge advantage.

Therefore we choose HHT to analyze CH_4 measurement data from atmospheric background station Mt. Waliguan during January 1991 to December, 2009, and have gotten four CH_4 intrinsic periods and the CH_4 yearly growth rate. The global growth trend of CH_4 is no deny, but how to discovery more knowledge about the source and sink from long time series measurement data deserves deep research. No matter the CH_4 source is naturally or anthropogenic, there is must some periods in principal. The four periods got by HHT method may have some links to methane source and sink and we will do more research in future

METHOD

The combination of the well-known Hilbert spectral analysis (HAS) and the recently developed empirical mode decomposition (EMD) [18-19], designated as the Hilbert-Huang transform (HHT) by NASA, indeed, represents a paradigm shift of data analysis methodology. The HHT is designed specifically for analyzing nonlinear and non-stationary data.

The basic steps of HHT is as following: (1) To extract a series of intrinsic mode functions from input signals and this step is called Empirical mode decomposition (EMD). Its core is the sifting process. (2)To make up a complex analytic function with every IMF and its corresponding Hilbert transform, and get the instantaneous amplitude and instantaneous frequency in the time domain and then get the time-frequency distribution of input signal amplitude, which is named Hilbert spectrum.

EMD method is based on the following three hypothesizes: (1) Input signal must have at least two extreme points, one maximum and one minimum. (2) Input signal characteristic time scale is decided by the time intervals between extreme points. (3) If there is no extreme point but there is singular point, it can show extreme point by differentiate once or more.

There are two basic requirements to satisfy the intrinsic mode function (IMF) definition: (1) In the whole data set, the number of extreme and the number of zero crossings must either equal or differ at most by one. (2) At any data point, the mean value of the envelope defined using the local maxima and the envelope defined using the local minimum is zero.

DATA PROCESS

The Waliguan Baseline Observatory (36°17′N, 100°54′E, altitude 3816m) is one of 24 baseline observatories of World Meteorological Organization (WMO) Global Atmosphere Watch (GAW), situated near the top of Mt. Waliguan at the edge of northeastern part of the Qinghai- Tibet lateau in a remote region of western China and showed in figure 1. The station is relatively isolated from major industrial sources and populated centers. The research data produced by Mt. Waliguan during January 1991 to December, 2009 and the data is monthly mean CH_4 concentration. Figure 1 is diagram of Waliguan atmospheric background station.

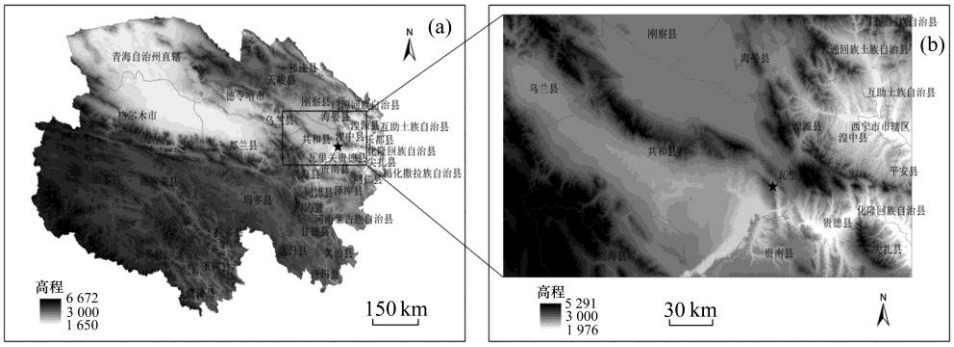

Fig.1 Diagram of Waliguan atmospheric background station

Measurement data and five IMFs and a trend which were extracted with EMD method from the measurement data showed in figure 2. From the figure, we can find that the period of IMF1 to IMF5 increases one by one. The last trend is a monotonic increase curve and that reflect during the measurement period the methane concentration total variation trend, and this meets very well with reality. It can be seen that instantaneous frequency deceases and period increase one by one. There are five intrinsic mode and their mean period are as follows: 4-month, 7-month, about 1-year, about 2-year about 5-year and 11- year.

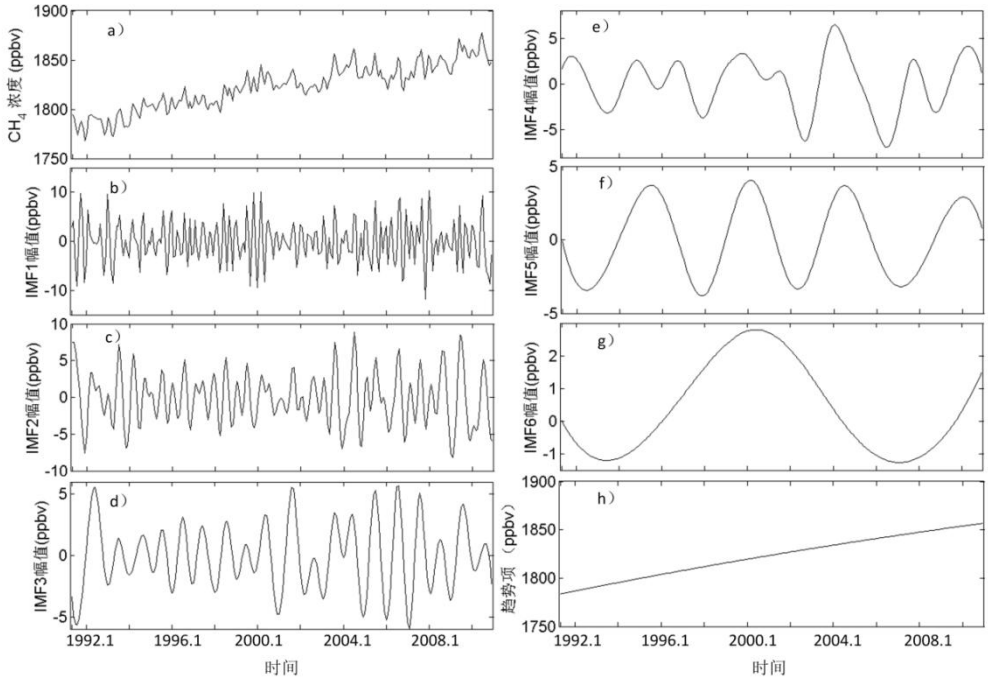

Fig.2 CH_4 concentration measurement data and IMF and trend of Waliguan between May, 1991 and December, 2010

CONCLUSION

Hilbert-Huang transform can extract the local adaptive periodic mean curve from non-linear, non-stationary raw data, and in the extraction process does not require any other a priori information. It can decompose the complex superposition of signal into a number of and have a clear physical meaning of the intrinsic mode functions, and can quantitatively analyze the sequence of time-frequency

characteristics, and obtain meaningful instantaneous frequency and Hilbert time-frequency spectrum. This paper discusses the use of Hilbert-Huang transform analysis of longer time series (1991.5 ~ 2008.12) observations of methane concentration, the use of EMD algorithm five items IMF and a trend. IMF can in the time domain with the original data very good contrast. Hilbert transform of the IMF, got five cycles of CH_4, respectively: 4-month, 7-month, about 1-year, about 2-year, about 5-year and about 11-year.

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