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Using Singular Spectrum Analysis for the Investigation of Troposphere Parameters

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Abstract. In this paper, the method of Singular Spectrum Analysis (SSA) is applied to the investigation of the zenith troposphere delay time-series derived from VLBI observations. With the help of this method we can analyze the structure of time-series and separate the harmonic and irregular (trend) components. Combined IVS time-series of zenith wet and total troposphere delays obtained at IGG were used for the analysis. For this study, several VLBI stations with the longest time series of troposphere zenith delays were selected, also taking into consideration the geographic region where the station is located. The investigations were carried out using SSA mode. As a result, trends and seasonal components (with annual and semiannual periods) were obtained for all the stations. Using of SSA enabled us to determine nonlinear trends in zenith delay, and also to study variations in the amplitude and the phase of the seasonal components with time.

1. SSA Method

In this research, we have investigated the combined IVS troposphere zenith delay (TZD) series and focused on behavior trends and seasonal components with the help of Singular Spectrum Analysis (SSA) [1]. Additional information on SSA method, its abilities and the corresponding software can be found on the site http://www.gistatgroup.com/cat/. With the help of this method we can:

– Recognize certain components in the equally spaced time series, which have been obtained from observations. The result of this procedure is a decomposition of the time series into components that usually can be identified as trends, periodical or oscillatory, and noise components.

– Extract components with well-known periods and estimate values of phase shift and variation of amplitude of pseudo-harmonic signals.

– Find periodicities that are not known in advance.

– Extract trends of different resolutions. Natural decomposition of the time series is constructed on the base of the unique parameter (the window length). Grouping different subsets of the decomposition components one can obtain both the tendency and accurate trend.

– On the basis of the chosen components smooth out the initial data.

In contrast to the standard spectral analysis, where the basic functions are given a priori as the sines and cosines of the Fourier method, in SSA they are determined from the very data to form orthogonal bases.

2. Analysis of Zenith Delay Time Series

The zenith total delay (ZTD) is the sum of the zenith hydrostatic (ZHD) and zenith wet delays (ZWD). The SSA method gives the opportunity to detect features of main ZTD and ZWD (ZD) trends and to compare them with the main trends of other time series, such as hydrostatic zenith delay, wet zenith delay, pressure at the site, temperature at the site, water vapor pressure at site, which were taken from the VMF1 files provided by the IGG. The combined IVS time series of ZD, obtained at IGG, were used in the analysis [2]. Six VLBI stations (Gilcreek, Kashima, Kokee, Onsala, Westford, Wettzell) with the longest time series of troposphere zenith delays were selected for the study. Linear interpolation of data was carried out to get equally spaced series with a step of 0.01 year which was used for SSA. For all time series we used the same time interval 1984.88 – 2004.87, series length N=2000 points (20 years), and the maximum window length M=N/2=1000. After decomposing with the SSA method in all series the trends, hereafter referred to as trend SSA, annual and semiannual components were found. Fig. 1–2 show ZD trends as obtained by SSA from the combined IVS series and their linear approximation. The fact that the stations located in the same geographic region (Onsala and Wettzell) reveal similar trend features is of special interest. Moreover, all trends have the same small curving about the year 1995. Original series obtained by analysis centers BKG, GSFC, IAA, MAO show the same properties, which are shown in Fig. 3 for Wettzell as an example.

It is interesting to compare non-linear trends found in the ZD with those in the meteorological parameters. For this purpose, the decomposition of the meteorological parameters for Wettzell and Gilcreek has been made using SSA. Fig. 4 shows the trends for the hydrostatic zenith delay, pressure at the site from the VMF1, and ZTD-ZWD computed from the IVS combined series. The coincidence of all these curves is obvious for Wettzell. For Gilcreek one can see a difference in shape of the curves. Fig. 5 shows the trends for wet zenith delay, temperature at the site, and water vapor pressure at the site from the VMF1 and ZWD. The ZWD trend is very close to the trend of water vapor pressure for the Wettzell. But for Gilcreek similar curves do not show such an agreement. Gilcreek is the only station where we failed to extract the trend of the site temperature series.

Fig. 6–7 show the annual and semi-annual components ZWD for the researched stations. The components have a steady phase but variations in

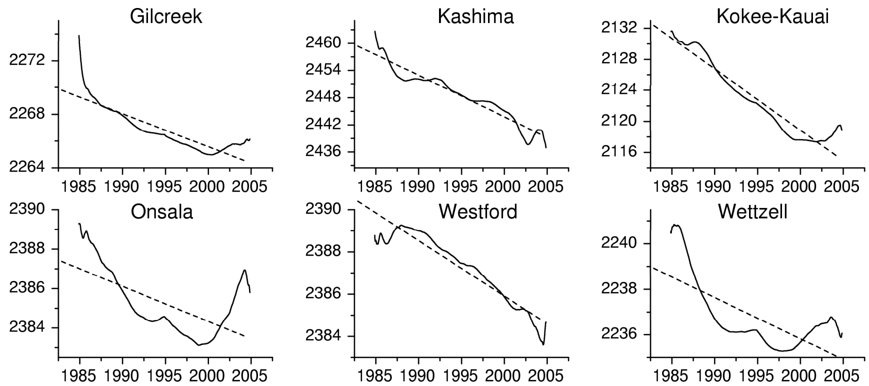

Figure 1. SSA trends of ZTD (solid line) and their linear approximation (dashed line). Unit: mm

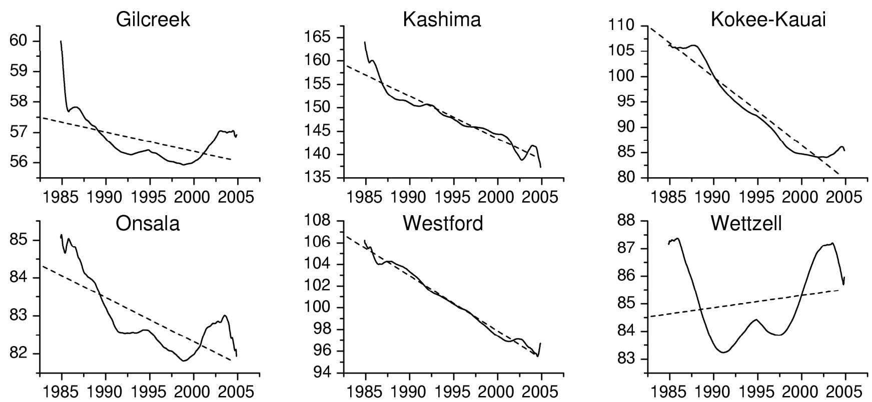

Figure 2. SSA trends of ZWD (solid line) and their linear approximation (dashed line). Unit: mm

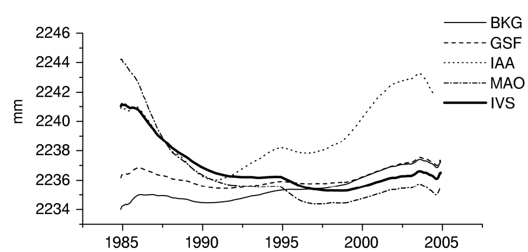

Figure 3. SSA trends in ZTD for individual series for Wettzell

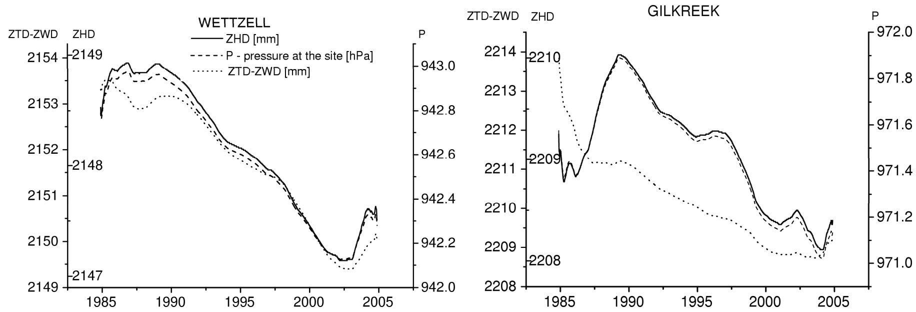

Figure 4. SSA trends of hydrostatic zenith delay, pressure at the site and ZTD–ZWD

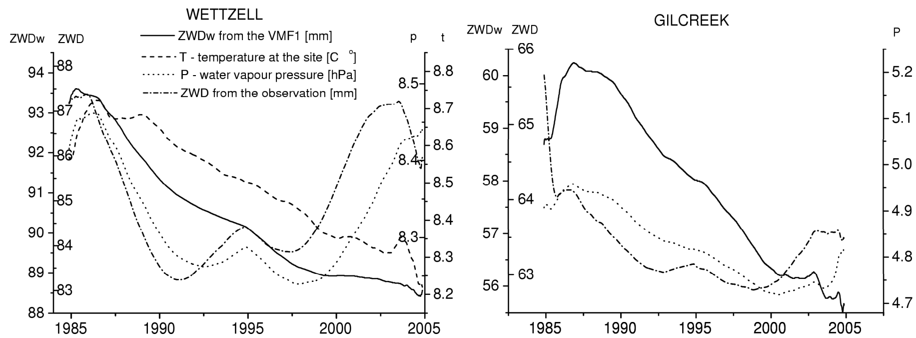

Figure 5. SSA trends of wet zenith delay, temperature at the site, water vapor pressure and ZWD

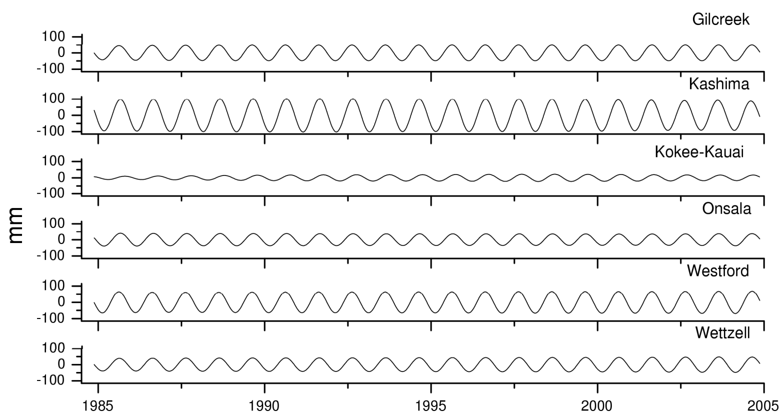

Figure 6. The annual components in reconstructed ZWD series

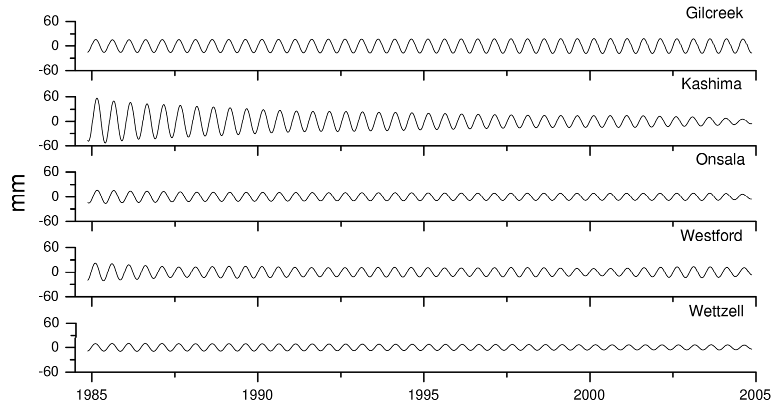

Figure 7. The semiannual components in reconstructed ZWD series

amplitude. It should be mentioned that the contribution of the semiannual component is comparatively small, near noise level, and therefore this component needs more careful study. For Kokee a semiannual component was not found, and so for ZTD at Onsala. For Kashima, the amplitude of the semiannual component is larger in the beginning of the time interval than at the rest of interval.

3. Conclusions

In this paper, we have examined the ability of the SSA method in the analysis of the zenith troposphere delay. Non-linear trends and variations of the amplitude of seasonal components have been detected. Some interesting peculiarities in their behavior have individual character for every site. A comparison of the trends with meteorological parameters also is presented to show possible similarities that deserve further investigations.

References

[1] Golyandina, N., V. Nekrutkin, A. Zhigljavsky. Analysis of Time Series Structure: SSA and Related Techniques. Chapman and Hall/CRC, New York, 2001.

[2] Heinkelmann, R., J. Böhm, H. Schuh. Combination of Long-term Time Series of Tropospheric Parameters Observed by VLBI. IVS 2006 General Meeting Proceedings. D. Behrend, K.D. Baver (eds.), NASA/CP-2006-214140, 2006, 341–343.