21ST INTERNATIONAL WORKSHOP ON LASER RANGING
5 – 9 NOVEMBER 2018
CANBERRA, AUSTRALIA

Session No: 2
Poster No: A6
Date : 5-6 November

# A common mode error explore for GNSS/VLBI/SLR/DORIS based on PCA method

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**Abstract**

With the improvement of the positioning accuracy of space technology, the residual time series of station coordinate not only reflects the traditional noises, but also contains more valuable information. The residual time series contains various non-linear movements that are not clearly identified by the current mechanisms. So, it is of great significance to further explore the information or errors from the residual time series for improving the accuracy of the reference frame and finding the common errors of every technique. In order to obtain the characteristics of residual time series, we introduce principal component analysis (PCA) method and wavelet transform to explore the Common-mode errors of the global coordinate residual time series of GPS, SLR, DORIS and VLBI stations. Common-mode errors are considered to be the main source of residual time series errors. We extract the main periodic terms from the station coordinate residual time series by Fourier transform. The data analysis show that the PCA method can decompose the space-time matrix into several orthogonal components and extract the principal components. Compared with the four technologies, most of GPS stations' coordinate residual time series shows obvious annual terms and the east-west linear drift. Due to the less stations and more missing data or less errors, the other three technical stations do not have obvious periodic term. Moreover, we also study the regional GPS continuous station coordinate residual time series with longer than 10 years such as Asia, Europe and North America. There is a significant annual periodic term signal.

## 1 Background

Global Geodetic Observing System(GGOS) requires the future TRF accuracy at 1mm in epoch position and 0.1mm/yr in change. But now the TRF accuracy is 5mm and 1mm/yr. So what errors is sill kept in TRF residual files and how to improve its accuracy? Therefore, we study the residual times series and find there are still some leaps ,linear trend undetected and secular motion especially in GPS residual times series. So we adopt Generalized outlier detection algorithm (ESD) and wavelet transform detect the new leaps and then do principal component analysis (PCA). By PCA we analysed the common errors from GPS,SLR,DORIS and VLBI and see if there are global system error in these 4 techniques.

## 3 PCA based on GPS residual times series

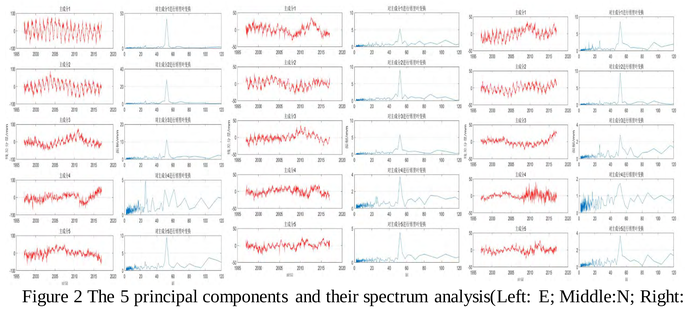

Figure 2 The 5 principal components and their spectrum analysis(Left: E; Middle:N; Right: U.

| Principal Component cumulative contribution rate | E 100% | N 100% | U 100% |
|---|---|---|---|
| 1 | 0.096408 | 0.117426 | 0.085731 |
| 2 | 0.155975 | 0.182974 | 0.152309 |
| 3 | 0.197033 | 0.232259 | 0.207099 |
| 4 | 0.234401 | 0.273138 | 0.249148 |
| 5 | 0.269512 | 0.308992 | 0.289539 |

## 2 Discontinuity detection based on ESD and detrend

We checked the TRF residual times series and detected the discontinuity based on ESD and did detrend. (See Figure 1).

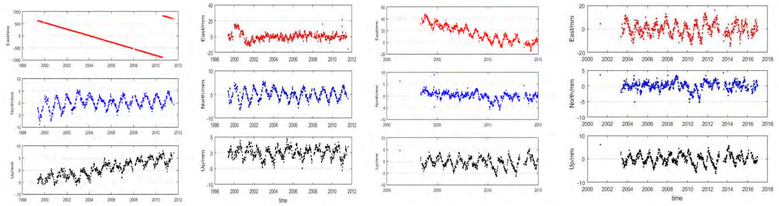

Figure 1 The detected the discontinuties based on ESD and detrend at AZCN (left) and CHPI(right).

| Principal Component | N period(**amplitude:mm**) | E period(**amplitude:mm**) | U period(**amplitude:mm**) |
|---|---|---|---|
| 1 | 1yr（2.0）、0.5yr（1.5） | 1yr（41.7） | 1yr（9.8）、0.5yr（2.9）、season（2.8） |
| 2 | 1yr（8.0） | 1yr（25.9） | 1yr（8.1） |
| 3 | 1yr（7.7） | 1yr（11.2） | 1yr（4.3） |
| 4 | 61.4weeks（2.0）、1yr（1.9） | 1yr（6.2）、0.5yr（4.7） | 1yr（3.1） |
| 5 | 1yr（5.6） | 1yr（11） | 1yr（3.9） |

## 6 Conclusions (continued)

◆A number of GPS station data and longer data length prove the accuracy and the feature extracted by the PCA method. There are anual signals in three directions of most of GPS stations based on the Fourier analysis of principal component. And also there are semi-anual and seasonal change in the first principal component of the GPS vertical and N direction. There are semi-anual signal in the first principal component of the GPS N direction and the fourth component of E direction. The amplitude in E direction is greater than the other two directions. the anniversary amplitude of the former three E direction principal components are 41.7 mm, 25.9 mm and 11.2 mm respectively. It shows that GPS stations mainly show the E direction displacement.

## 7 Acknowledgments

We thank National Natural Science Foundation of China (NSFC) (No. 11173048) and Ministry of Science and Technology of China( No.2015FY310200) for funding.

## 4 PCA based on SLR residual times series

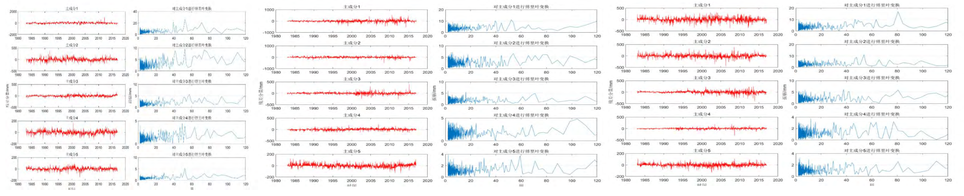

Figure 3 The former 5 principal components and their spectrum analysis(Left: E; Middle:N; Right: U.

## 5 PCA based on DORIS and VLBI residual times series

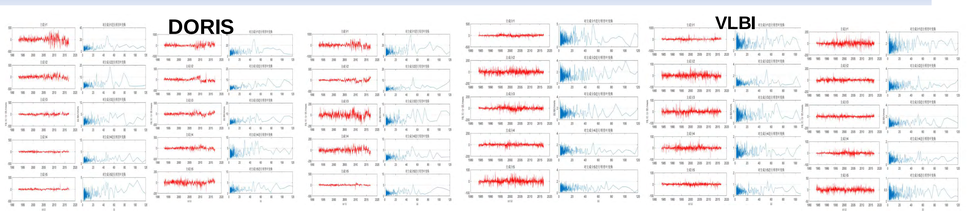


Figure 4 The former 5 principal components and their spectrum analysis(Left: E; Middle:N; Right: U.

## 6 Conclusions

◆298, 28, 34 and 20 principal components, spatial features vector and the principal component features values are calculated based on GPS, SLR, DORIS and VLBI residual times series separately. All three directions in 4 techniques has high frequency noise signal. It maybe was mainly caused by the interpolation.

◆There are the obvious anual signals in the first and second principal components of SLR data. There are 80 weeks period signal at amplitude about 17 mm in the first component of the vertical direction but its mechanism is not clear.

◆There are time change with jump and drift in the vicinity of 2010 from DORIS three principal component. That is maybe caused by status or satellite configures changed.

◆There are no obvious period signal in VLBI residual time series. The amplitude in E and U direction is less than 5 mm and that in N direction is less than 10 mm.

◆Compared with GPS, the residuals of other techniques has less obvious and smaller period signals. It shows there are maybe less error source types or less integrity data or uneven distribution data.