STUDY ON GPS STATION'S ZENITH DELAY TO MITIGATE THE INSAR ATMOSPHERE EFFECT

LI Tao[a] , ZAHNG Shiyu[a], Zhang Shuangcheng[a], LIU Jingnan[a] , XIA Ye[b]

[a] GNSS Research Center of Wuhan University, 129 Luoyu Road,Wuhan, 430079, China - taoli@whu.edu.cn
[b] GeoForschungsZentrum Potsdam, Germany - xia@gfz-potsdam.de

Commission VII, WG VII/2

KEY WORDS: Atmosphere, SAR, GPS, Temporal, Correlation, Climate

ABSTRACT:

Both InSAR and GPS can detect tropospheric delay of radar beam propagation caused by water vapour fluctuation. What InSAR detected is the differential results of two SAR images taken at two epochs whose spatial resolution can be tens of meters. GPS can continuously detect tropospheric delay above the station and average the final results into zenith direction. But as GPS stations spans tens of kilometres, the final interpolated tropospheric delay in space is very poor and it depends on the distribution of GPS stations. This paper studied the tropospheric delay on Tandem interferogram in Tianjin area. Using surface fitting method in baseline error correcting, both the baseline error and the whole scene tropospheric delay were suppressed. Meanwhile, 13 GPS continuous operating stations in Tianjin were used to calculate the zenith delay over each station. GAMMIT software is used to get the zenith delay according to the Tandem SAR image acquiring season and epoch. The spline method was used to interpolate the zenith delay to the SAR image area and corresponding results were helpful to mitigate the tropospheric delay on Tandem interferogram. This study shows that GPS zenith delay may be useful to mitigate the tropospheric delay in InSAR.

1. INTRUDUCTION

InSAR technique is widely used in topography mapping and surface displacement. However, the results were sensitive to the satellite orbit errors, tropospheric effect, decorrelation, and so on.

In 1994, Massonnet firstly found the tropospheric effect in interferograms while studying Landers earthquakes. After that, many researchers paid attention to this field. Hanssen used 26 Tandem ERS interferogram to study the tropospheric delay effect in Netherlands and the results showed that tropospheric delay in interferograms may be 0.3 to 2.3 circles. In 2004, Li Zhiwei, et.al testified that the tropospheric errors in interferogram can not be regarded as Gaussian distribution which means we can not use averaging method to mitigate this kind of errors. In 2005, Li zhenhong, et.al proposed a new method to interpolate the GPS zenith day in large area considering the topography and correlation among the GPS stations which is called GTTM(Topography-Dependent Turbulence Model). Using this model the MODIS data can be rectified and the fusing data of GPS/MODIS turned to be more accuracy than before. However, MODIS data is not so appropriate for InSAR because it is sensitive to cloudy condition.

This paper used 13 GPS continuous operation stations and the tandem interferogram in Tianjin area to study the correlation between the two data. The results showed that both methods can measure the tropospheric delay very accurately, but as GPS stations are located sparsely its final resolution may not satisfy the InSAR correction.

2. TROPOSPHERIC DELAY

2.1 Tropospheric delay

The reflection rate of the microwave can be regarded as a variable along the propagation path. The tropospheric delay can be accumulated by the following function:

$$S = \frac{1}{10^6 \cos\theta_{inc}}\left(\int_0^H N_{hyd}dh + \int_0^H N_{wet}dh\right) = S_{hyd} + S_{wet} \tag{1}$$

where H = the height of troposphere
θ_{inc} = the incident angel of the radar beam,
N_{hyp} = the hydro reflection rate
N_{wet} = the wet reflection rate,
S_{hyd} = the dry delay
S_{wet} = the wet delay

Using the observations of the local temperature, atmospheric pressure and the atmospheric humidity, tropospheric delay can be calculated. Using this result as an initial one, GPS software carried out more accurate zenith delay in every one hour or every one quarter. Every one minute zenith delay may not be reliable for this may arise too much variables to the function and cause false results.

2.2 Tropospheric delay and interferogram phase

In interferogram, the tropospheric delay can be derived by phase variation:

$$\Delta\varphi = \frac{4\pi}{\lambda}\frac{ZWD}{\cos\theta_{inc}} \quad (2)$$

where $\Delta\varphi$ = the phase changes of two SAR images
λ = the RADAR wave length
ZWD = the zenith wet delay
$\cos\theta_{inc}$ = incline angle of radar wave

According to the experiments, 1 mm precipatable water vapour (PWV) may cause 6.2 mm ZWD delay. Equation (2) showed that water vapour can cause phase changes on interferograms. On the other side with special data processing, fringes on interferograms can also derive water vapour changes between two SAR image acquiring.

3. INSAR AND GPS MONITORING TIANJIN AREA

3.1 Interferogram of Tianjin area

A differential interferogram is derived by tandem image (2 Mar.1996 and 3 Mar.1996). Precise orbit is used to remove the flat earth effects, and SRTM3 DEM is used to remove the topographic effects. Displayed in Figure 1 are the interferogram and the coherence map.

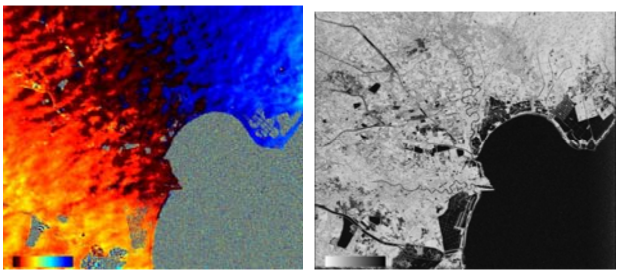

Figure 1. Tandem differential interferogram (left) and coherence (right) in Tianjin region

The phases are unwrapped with branch-cut methods, as are showed in Figure 2(A). From the unwrapped map, we can see that there is a colour ramp form the low left to the top right. Obviously this ramp is not caused by tropospheric delay but baseline errors. After the baseline errors are removed with curvature surface fitting method, the residual phases are decreased down to below 5mm (Figure2 B)

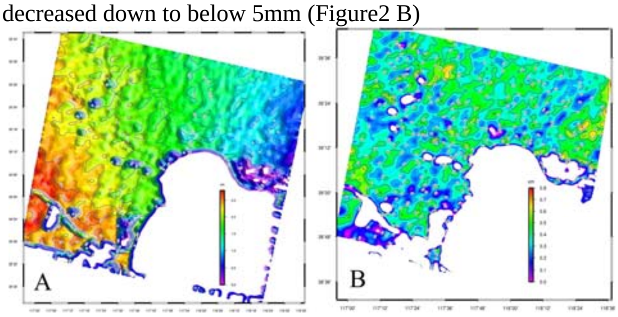

Figure 2. Comparison of tropospheric delay along radar line of sight between before and after removing baseline errors with curvature surface fitting method

3.2 GPS continuous operation stations in Tianjin

The location of the 13 GPS continuous operating stations, as well as Tianjin district boundary and SRTM-3 DEM are displayed in Figure 3.

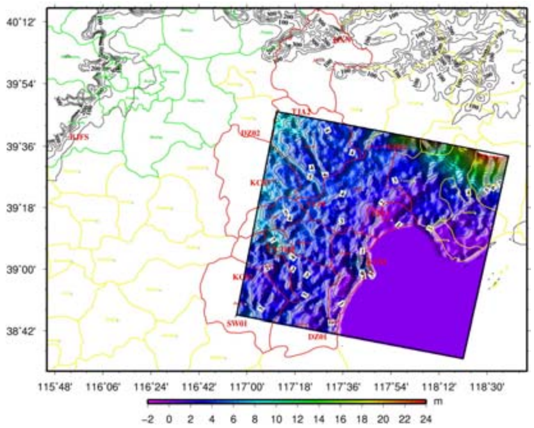

Figure 3. Map of Tianjin district boundary, SRTM-3 DEM and GPS station distribution

According to the Tandem SAR image acquiring season and epoch, the zenith delay over each station is calculated, as is shown in Figure 4.

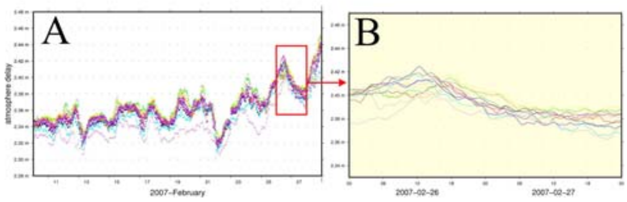

Figure 4. GPS zenith tropospheric delay variation at Tianjin region in Feb 2007

The total tropospheric delay on 2 and 3 Mar 2007 at 13 stations are interpolated over the whole tandem image, which is shown in Figure 5.

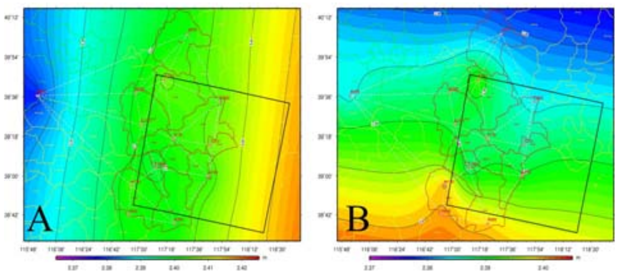

Figure 5. Interpolation map of GPS total tropospheric delay at Tianjin region on 2 and 3 Mar 2007.

The differential interpolated tropospheric delay between 2 and 3 Mar 2007 is shown in Figure 6 (A),.on which a colour ramp exits from the low left to the top right, same to Figure 2 (A).

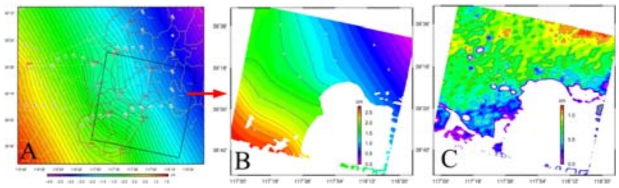

Figure 6. 24 hours GPS tropospheric delay variety map and differential between InSAR results

The corresponding region to the tandem image is selected, as shown in Figure 6 B. After the interpolated GPS tropospheric delay is subtracted from the differential interferogram (Figure 2A), the phases are decreased down to below 1cm (Figure 6C). From Figure 6, we can see that the tropospheric delay within GPS network is greatly mitigated (about 5 mm), while due to the interpolated errors the results outside the GPS network are not perfect.

4. RESULTS AND DISCUSSIONS

From the comparison between the GPS-derived zenith total delay and the delay on interferogram, we can see the value levels, the spatial distribution and the patterns of the error are the same.

Even though the troposphere delay exhibits random characteristics, the GPS-derived zenith total delay can effectively remove such effects on interferogram. However, due to the sparse distribution of GPS stations, the interpolated GPS-derived zenith total delay can only represent the trend over large extend, and cannot reflect the details of troposphere at small scale.

ACKNOWLEDGEMENTS

This paper is funded by the National Natural Science Foundation of China (No.40604002 No.40474002). It is also supported by the Programme of Introducing Talents of Discipline to Universities (No.B07037). The interferometry processing in this paper was performed by the freely available Doris software, developed by Delft University of Technology.

REFERENCES

Bevis, B.G., S. Bussinger, T.A. Herring, C. Rocken, R.A. Anthes, and R.H. Ware, 1992. GPS Meteorology: Remote Sensing of Atmospheric Water Vapor Using the Global Positioning System J. Geophys. Res., 97,pp.15787-15801.

Hanssen,R.H., 1998. Radar Atmospheric Heterogeneities in ERS Tandem SAR Interferometry Delft, the Netherlands: Delft University Press,.

Hanssen R.H., T. M. Weckwerth, H. A. Zebker, and R. Klees., 1999. High Resolution Water Vapor Mapping from Interferometric Radar Measurements Science, 283,pp.1295–1297.

Hanssen R.H., 2001.Radar Interferometry-Data Interpretation and Error Analysis Netherlands: Kluwer Academic Publishers.

Davis,J.L.,T.A.Herring,I.I.Shapiro,A.E.E.Rogers,and G.Elgered.,1985. Geodesy by Radio Interfer- ometry: Effects of Atmospheric Modeling Errors on Estimates of Baseline Length Radio Science, pp. 1593-1607.

Baby,H., P.Gole,and J.A.Lavergnat., 1998. Model for Tropospheric Excess Path Length of Radio Waves from Surface Meteorological Measurements Radio Science, pp. 1023-1038.

LI Tao, LIU Jing-nan., 2003.Deformation Detecting Algorithms with Auxiliary GPS Data in SAR Interferogram . Proceedings of SPIE, pp. 5286(871-874).

LI Tao, LIU Jing-nan,LIAO Ming-sheng, et al. 2004. Monitoring City Subsidence by D-InSAR in Tianjin Area. IGARSS 2004 Proceeding, Anchorage Alaska USA.

Massonnet,D., K.Feigl, M.Rossi, and F.Adragna.1994. Radar Interferometric Mapping of Deformation in the Year after the Landers Earthquake Nature, pp., 369(227-230).

Rocken, C., R.H. Ware, T. Van Hove, F. Solheim, C. Alber, J. Johnson, and M.G. Bevis. 1993. Sensing Atmospheric Water Vapor with the Global Positioning System Geophys. Res. Lett., 20,pp.2631-2634.

Sasstamoinen,J. 1972. Atmospheric Correction for the Troposphere and Stratosphere in Radio Ranging of Satellites . Geophysics monograph 15,3rd Int.SympUse of Artificial Satellites for Geodesy, AGU, pp. 247-251.

Zebker, H. A., P. A. Rosen, and S. Hensley.,1997. Atmospheric Effects in Interferometric Synthetic Aperture Radar Surface Deformation and Topographic maps J. Geophys. Res., B4, 102,pp.7547-7563.

Zhenhong LI. 2005. Correction of Atmospheric Water Vapour Effects on Repeat-Pass SAR Interferometry Using GPS, MODIS and MERIS Data University College London.

Zhiwei LI. Modeling 2005.Atmospheric Effects on Repeat-pass InSAR Measurements. Hong Kong Ploytechnic University,.